POWER

Established 1884—McGraw-Hill Publishing Company, Inc.

VOLUME 75 MAY 31, 1932 NUMBER 22

ELY C. HUTCHINSON, *Editor*

WITH HONOR

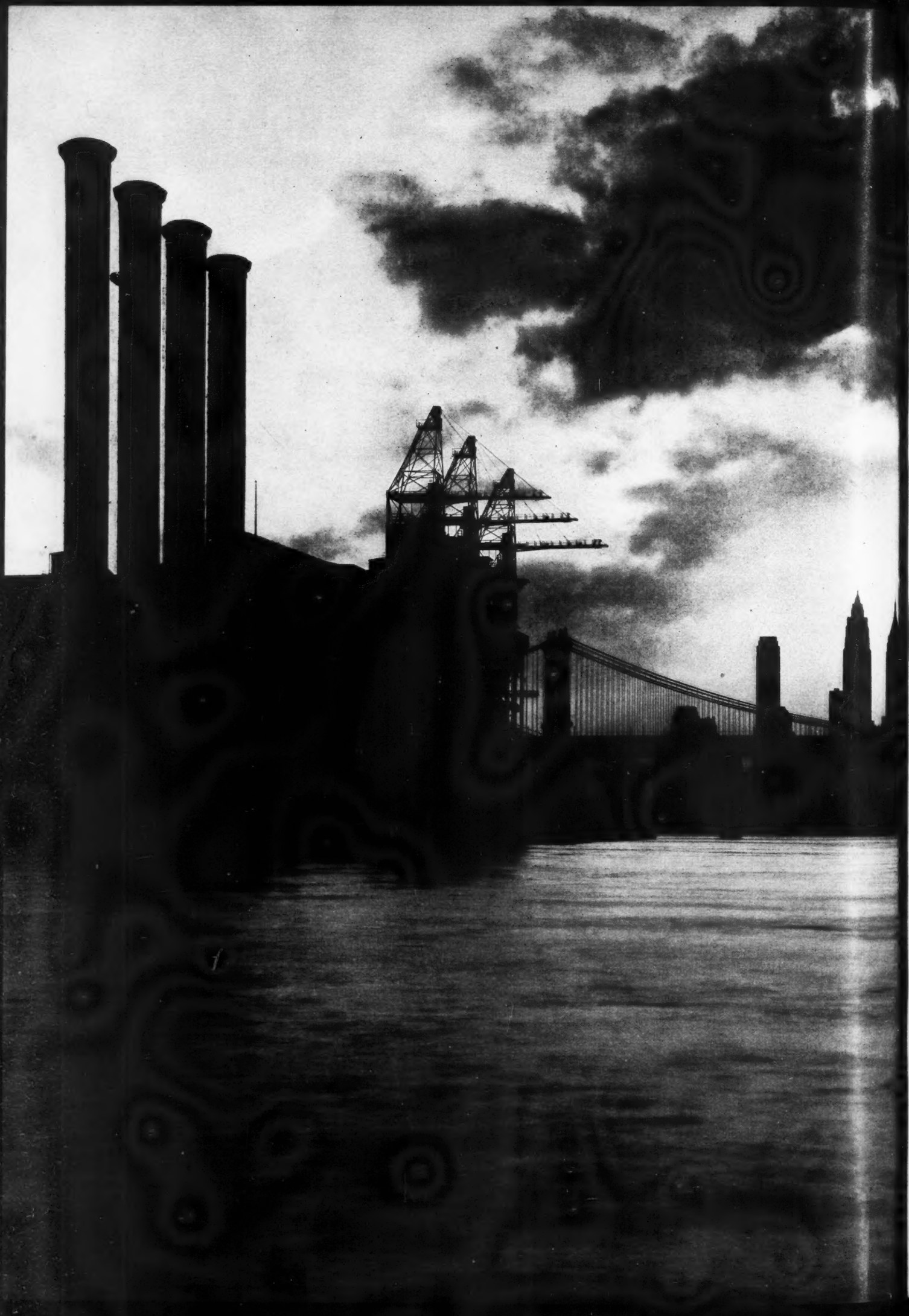
ALL GLORY to the spirit and courage of those who support vision with action and so lead the advance armies of the present civilization! It is a far cry from Branca's steam wheel of sixteen hundred twenty-nine to Sir Charles Parson's first turbine of eighteen hundred eighty-four.

Yet the span of Sir Charles' lifetime, so recently closed, has seen the most vivid imaginations of our time realized and surpassed. Scarcely has one record steam power installation been well under way before being superseded by a greater one. And at the bottom of it all has been the unlimited readiness of the world to accept the manifold benefits of a power-operated civilization.

Nowhere is this great development better exemplified than in the inception and growth of the Hudson Avenue station of the Brooklyn Edison Company. Started in nineteen hundred twenty-two with the, then, highly courageous intention of an ultimate growth to four hundred thousand kilowatts in eight units of fifty thousand each, this year finds it finally finished as the world's largest steam power plant with a capacity of seven hundred seventy thousand kilowatts.

Its last two units are of one hundred sixty thousand kilowatts each and the intervening units mark the successive steps of design accomplishment, so that the station in effect is a living pageant depicting the development of the art in the last decade.

As a fitting tribute, then, to those whose vision, courage, scientific and technical skill have given this monument to the world, this number of *Power* is respectfully dedicated.



HUDSON AVENUE STATION

• 1922-1932 •

By JOHN C. PARKER
President, Brooklyn Edison Co.

THE INITIATION, construction and completion of a major generating station within a period of ten years, and the prosecution of that work by the same group of men, has presented rather unusual opportunity for consistent design. This I believe to be the outstanding characteristic of Hudson Avenue generating station.

Initiated in 1922 with the installation of two turbine-alternators of the largest size which the manufacturers were at that time willing to produce, the station is now being completed with the installation of two units of the largest size yet built in single-shaft machines, and in the intermediate stages of development, turbines, condensers, boilers and stokers have followed a similar program of development in maximum sizes available.

The soundness of this program has amply demonstrated itself through the inter-connection with the other stations in the New York territory, which, though it did not exist at the time of the initiation of the station, was the obvious and logical thing to do and which became possible under unified operation. Thus units, large relative to the requirements of the Brooklyn Edison Company, became relatively of somewhat modest size when set against the background of the total requirements of the metropolitan area.

The generating station started with stoker-fired boilers, and is being completed with the same general type of combustion equipment. The engineers of Brooklyn Edison Company do not believe that for all locations or under all conditions of design, stokers should necessarily be used. I believe they would agree with me that, adopting either one of two closely alternative methods and consistently putting one's best efforts into perfecting that method, any group can do better than by shifting from one fundamental method to another, a fact which is often lost sight of in the prosecution of design. This simply says that the mental effort and the detail changes necessitated by re-adaptation from one technique to another would, in most cases, probably better be spent in the perfection of the technique originally adopted. At the least, it is the judgment of our group that we have been able to consolidate into the later stages of the design the results of experience—adverse and favorable alike—gained in the initiatory stages.

As to the electrical features, the same progressive development has taken place. The station was designed from the outside in. Electrically, the whole layout revolved about the distribution system rather than about the generators. This philosophy has run through to the completion of the design.

By the foregoing I do not mean to suggest that the successive installations have been Chinese copies of their predecessors. Quite to the contrary, the requirements for more and more generating and distribution capacity within a given space, and the enlargement of our own vision as to our specific requirements in the distribution system, have necessitated painful adaptation of space and structure to an enlarged view of the requirements.

The development in the art of higher steam pressures has required progress from an initially rather modest pressure to higher pressures and greater steam temperatures. Unquestionably, with a station being started anew today there would be very good reason for going to much higher pressures and starting with larger units than those now being completed, and the electrical outlets from the station would reflect a more matured view of the requirements of the territory.

We do not regard the Hudson Avenue generating station as by any manner of means the last word in development in Greater New York. It is presented to the industry merely as a consistent study in evolution and adaptation.

BUILDING TO THE POWER DEMAND

CONCEPTION, ENGINEERING AND GROWTH OF HUDSON AVENUE STATION

By G. L. KNIGHT
Vice-president
Brooklyn Edison Company

IN 1921 consideration of the rapid progress of the Brooklyn Edison Company during the previous ten years, doubling its output as it had done in five years and doubling the number of customers in three, led to adoption of a plan of expansion for the next ten years, conservatively predicated on past experience, of far greater scope than any previously contemplated. This comprehensive plan included measures to meet the future requirements of capacity and of economy; to standardize and simplify the type of service in phase and frequency; and further to decrease its cost of distribution and increase its efficiency—all tending to improve and lower the cost of general service.

Growth of the Load

In the Fall of 1921 the maximum load had been 133,500 kw. and, predicated on the previous rate of growth in the tabulation below, it was expected that the maximum demand by 1926 would be 275,000 kw. and perhaps 550,000 kw. by 1931.

	Net Instantaneous Max Demand Supplied to H-T Feeders for Brooklyn		Net Instantaneous Max Demand Supplied to H-T Feeders for Brooklyn
1911.....	34,267	1917.....	76,350
1912.....	41,363	1918.....	84,150
1913.....	46,900	1919.....	103,400
1914.....	47,950	1920.....	113,600
1915.....	60,500	1921.....	133,500
1916.....	65,750		

The two then-existing generating stations of the company, the 25-cycle station at Gold Street and the 60-cycle station at Sixty-sixth Street, had been developed to their maximum economic capacities—125,000 kw. in the first and 65,000 kw. in the second—so that it was necessary to consider another generating station site.

The site secured, between the foot of Hudson Avenue and the United States Navy Yard, about 4½ acres, extended along the waterfront of the East River for about 450 ft. There was available an ample supply of good condensing water, excellent possibilities for developing first-class coal-handling facilities, and underlying the entire property a body of fine sand which was believed to assure firm foundation footings.

Responsibility for the station design was placed on the electrical and mechanical engineers of the company, aided by the operating superintendent. The administration was carried out by an engineering committee reporting weekly to the president, through which committee was reported every important item of design, cost, scedule and operation.

The fundamental thought was to build a station along conservative lines which would combine simplicity of arrangement, steam conditions predicated on successful experience, and in general such features as would give uninterrupted service with the greatest economy consistent with reliability. The initial selection of what now seem very moderate steam conditions (275 lb. and approximately 610 deg.) was made advisedly because of the availability of large equipment that had satisfactorily operated at this pressure in several stations then recently placed in operation. While equipment for operation at higher pressures was then being offered in smaller sizes, it was felt that these conservative steam conditions would best assure reliable operation.

In 1922, when decision was reached as to the general arrangement and physical limitations of the new generating station, it was determined to use the largest turbine-generator units then offered by the manufacturers, since greater economy and a lower cost per kilowatt would be secured. It was also decided to lay out the maximum number of these units that the station site would accommodate.

Studies carried on with the manufacturers determined the selection for the first two units of two equally promising 50,000-kw. turbines, one a single-expansion impulse machine of 21 stages from the General Electric Company, and the other a Westinghouse tandem-compound reaction turbine. The steam conditions were set at 275 lb., 200 deg. superheat, with full-load requirement at 80 per cent power factor and 28 in. vacuum.

The boiler plant consisted of four stoker-fired boilers per turbine, without water walls, which were developed later, and without economizers. Natural draft was used on the induced side and forced draft was provided with direct-current motors on Ward Leonard control.

Site and Description of Foundations

Many schemes for the foundation structure were suggested and estimated and it was finally decided to place the whole structure on piles driven or jetted to refusal in the fine sand which underlay the property. Difficulties were encountered in constructing the tunnels and foundations, as piles had to be driven and cut off and concrete placed at levels 35 to 45 ft. below the river surface. This work was done in eleven cofferdams sunk to the required depth through old fill, stone cribs, and other obstructions. Fine sand, when properly confined, is one of the best bases on which to build, but when under water and subjected to unbalanced pressures in cofferdam work it is a most uncertain and dangerous material. The tunnels and building and turbine foundations were completed successfully despite these conditions and have never given the slightest trouble.

During this period of construction, and before the first two units were put into operation, it was decided to order a third turbine. This was ordered from the Westinghouse Company as a duplicate of No. 2 machine.

In the first section to be completed provision was made for only three turbine-generators with their boilers and auxiliaries, and not until 1925-26 was the second

and final section of the building completed. This provided for five additional units.

When it became certain that additional capacity would be required about the Fall of 1926 a careful review of experience and the development of the art was made to see whether it would be better to continue with the sizes of units and steam conditions with which the station had started or to make a change. It was finally decided that the economies to be realized by raising the steam pressure to 400 lb. and the temperature to 700 deg. would justify the slight disadvantage of two pressures in the station, and that it would be practicable to install an 80,000-kw. unit. This time a cross-compound turbine-generator was selected. A considerable improvement in heat balance was indicated by increasing the turbine bleeding to four points and installing air preheaters, together with an increase in boiler heating surface and the installation of water walls on the three sides of the furnaces. This made the boilers capable of delivering 290,000 lb. of steam per hour each as compared to the 146,000 lb. per hour of the first three rows.

While the resulting economies were satisfactory, the structural difficulties and space requirements of the hot air duct proved so difficult to handle that, when No. 5 unit was under consideration, the advantages of economizers and two-stage bleeding as against air heaters with four-stage bleeding were carefully weighed. Although a slight loss was indicated for the first compared to the second of these alternatives, it was felt that the construction program and schedule could be met with greater surety and a much simpler and more accessible assembly could be provided. This prediction was more than borne out during the construction program, and the arrangement adopted for No. 5 has been carried out throughout the rest of the station.

When No. 5 unit was under consideration the boilers were taken up first. The largest possible reliable heat output was first ascertained and this output was given to each turbine manufacturer with a request that he bid on a turbine-generator to produce a maximum output from that amount of heat. This resulted in the selection of a 110,000-kw. cross-compound Westinghouse turbine supplied from four boilers each having a capacity of 350,000 lb. per hour. This decision was reached in the early winter of 1927-28, so that, less than four years after the start of operation of the first two 50,000-kw. turbines the size of turbine-generator unit had been more than doubled, and the boiler output more than doubled, yet the equipment was being installed in the space originally laid out for 50,000-kw. units.

Company growth required that further capacity be available in 1930, and as it then seemed impracticable further to increase the size of unit, principally because of boiler and stoker limitations, it was decided that the cheapest and most reliable installation would be a duplicate, including boilers and stokers, of the No. 5 unit just completed. This was done and great savings were made in the installation cost and in the time of erection. This unit became available for operation in October, 1930.

Since that time the generating stations of the electric companies affiliated with the Consolidated Gas system have been operated together for maximum system economy. Two 160,000-kw. cross-compound units had been installed at the Hell Gate station of the United Electric Light & Power Company, and at the East River station of the New York Edison Company a 160,000-kw., 100 per cent power factor, 25-cycle tandem-compound unit had been recently placed in service, in each case filling the available space in the station. As further increase in the 60-cycle capacity was desired by the system for 1932 operation, and as the Hudson Avenue station had complete housing, condensing tunnels and coal-handling facilities, it proved to be the cheapest point for installing additional system capacity.

As the problem was to get the two largest units that could be furnished with adequate steam supply, attention was first directed to the boiler room to see what maximum steaming capacity could be provided. It was found that, with eight boilers and stokers of the capacity and type used in the No. 5 and 6 rows installed inside the boiler house for which space was available, and with an additional boiler house on the dock containing two slightly larger boilers and stokers, the size of turbine unit could be increased to approximately 160,000 kilowatt.

With sufficient steaming capacity potentially available, attention was concentrated on a turbine room layout suitable for two 160,000-kw. units. The so-called vertical-compound type machine was first considered, but it was finally found possible to get a bid on tandem-compound machines of the type installed at East River station but of 60 cycles, 80 per cent power factor, which meant a 200,000-kva., 1,800-r.p.m. generator as compared to the 160-000-kva., 1,500-r.p.m. generator at East River.

With this possibility determined, involving the raising of the turbine room floor some five feet to get sufficient condenser capacity to provide a maximum load vacuum of $27\frac{3}{4}$ in. with summer circulating water temperature, negotiations with the boiler and stoker manufacturers established that one stoker manufacturer was willing to guarantee the desired steam output from eight boilers instead of the ten contemplated. It was relatively easy to increase the boiler size to correspond with the larger stoker, so that steam-generating equipment has been provided with guarantees of sufficient capacity to supply two General Electric 160,000-kw. turbines.

It was found that the desired increase in steaming capacity could best be obtained within the limitations of the existing boiler house with bent-tube boilers. Eight such boilers rated at 530,000 lb. of steam per hour were installed. These were accompanied by relatively large economizers, since air preheat had been found undesirable after the No. 4 unit installation.

Detailed study of auxiliary drives has led to an increasing use of alternating-current squirrel-cage motors, which has, in turn, weighed heavily in the choice of vane-controlled fans and hydraulic drive for the stoker mechanism.

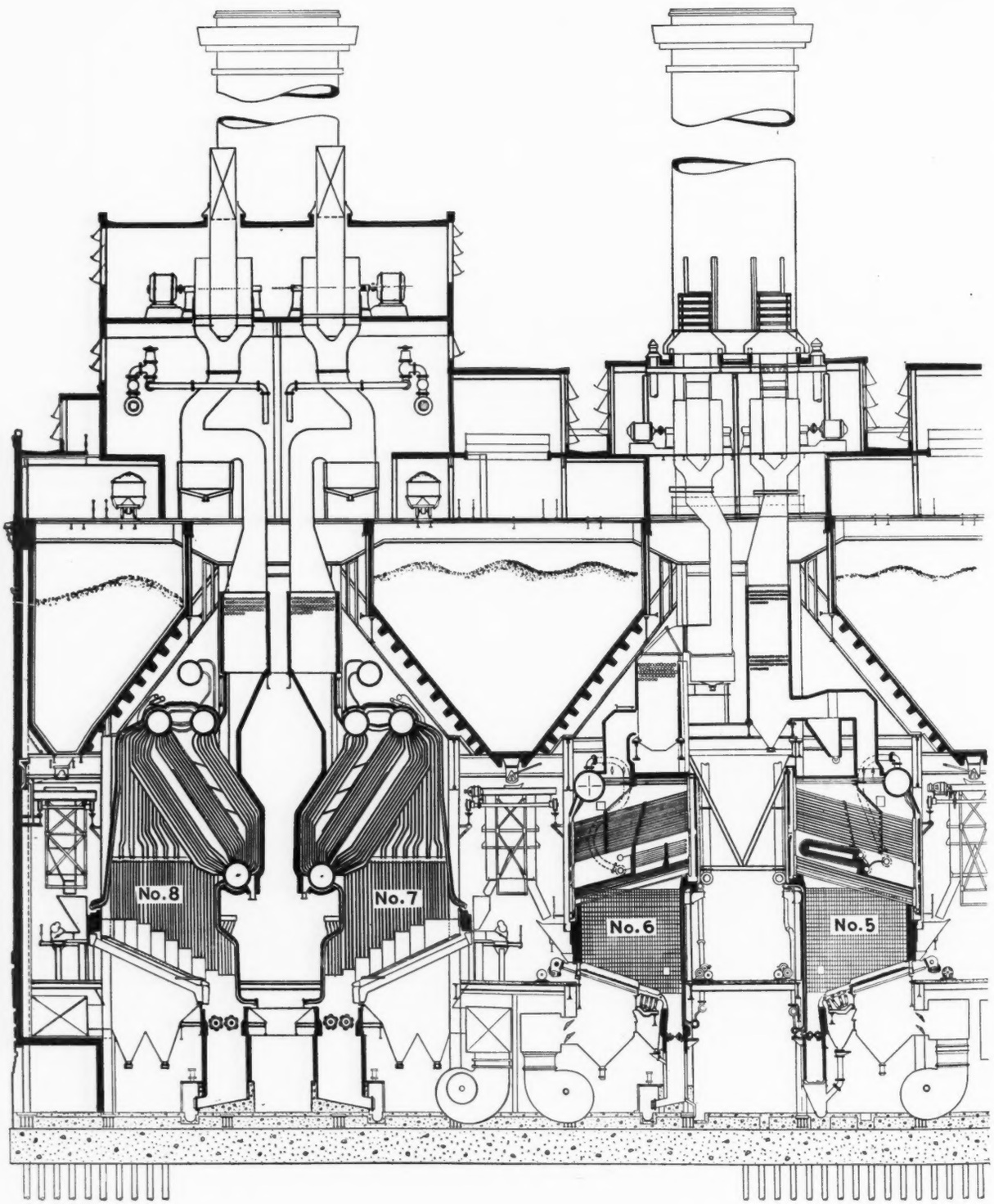
With the installation of the two generating units, one of which has been in successful operation since the last of January of this year, and the other having just been started, the Hudson Avenue station is complete with eight units, but instead of eight 50,000-kw. units totalling 400,000 kw., as originally contemplated, the installed capacity is 770,000 kw., or nearly twice that at first expected to be the ultimate capacity.

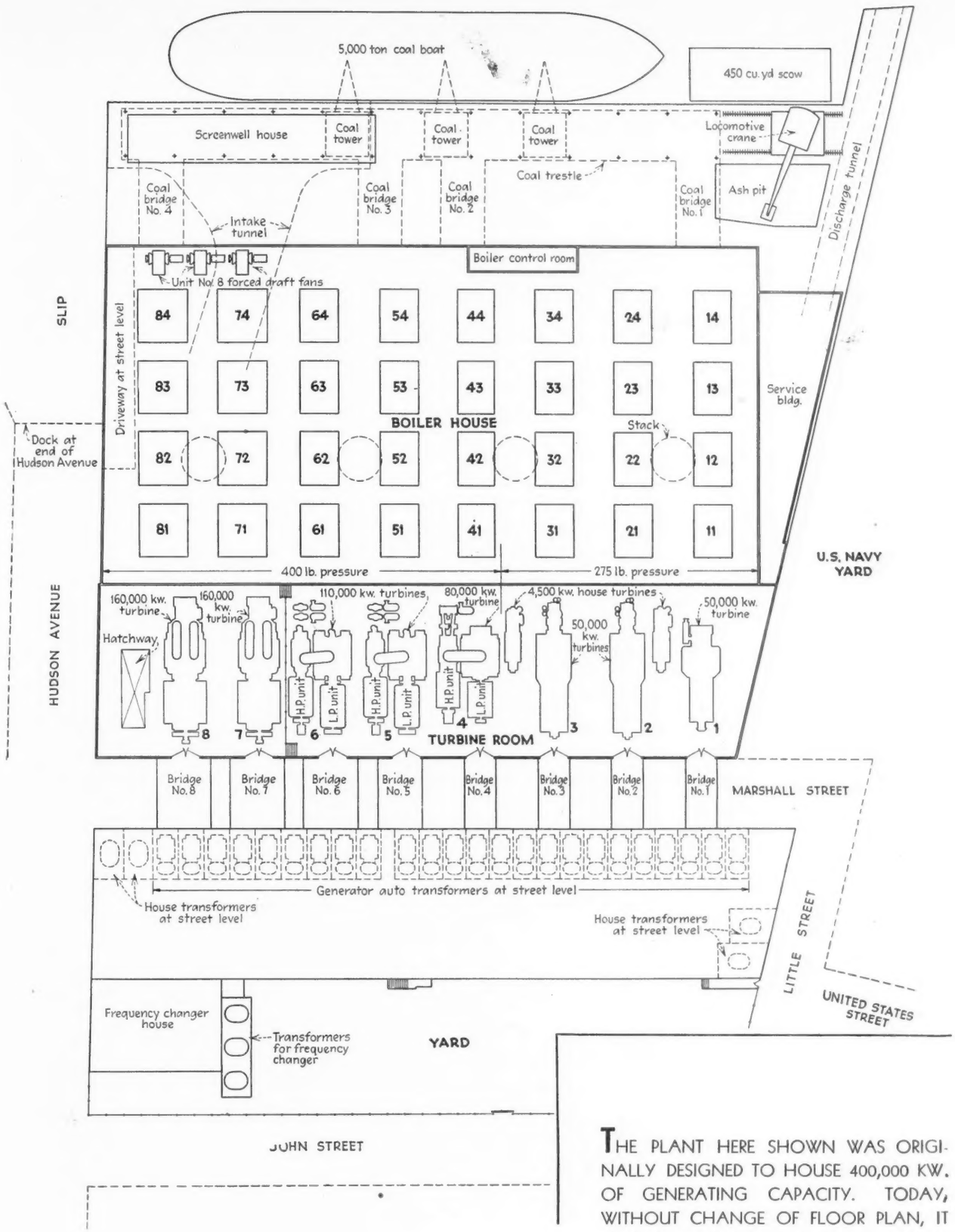
With the increase in capacity there has come about a marked decrease in the cost per kilowatt of installed capacity and a commendable increase in economy. When the carrying charges on the capital investment and the operating charges are considered together, as they should be in any generating station development, it is believed that those for Hudson Avenue will compare favorably with anything that can be shown.

PARTIAL PLANT SECTION

A GRAPHIC RESUME OF BOILER PROGRESS

MOST NOTABLE CHANGES IN HUDSON AVENUE BOILERS ARE FOUND IN THOSE FOR UNITS NOS. 7 AND 8 (THE LAST EXTENSION) WHICH MAY HERE BE COMPARED WITH THOSE OF UNITS NOS. 5 AND 6. THE NECESSITY OF ACHIEVING AN UNPRECEDENTED CONCENTRATION OF BOILER CAPACITY WITHIN THE FIXED SPACE LIMITS LED TO THE DESIGN ADOPTED FOR THE LATEST BOILERS

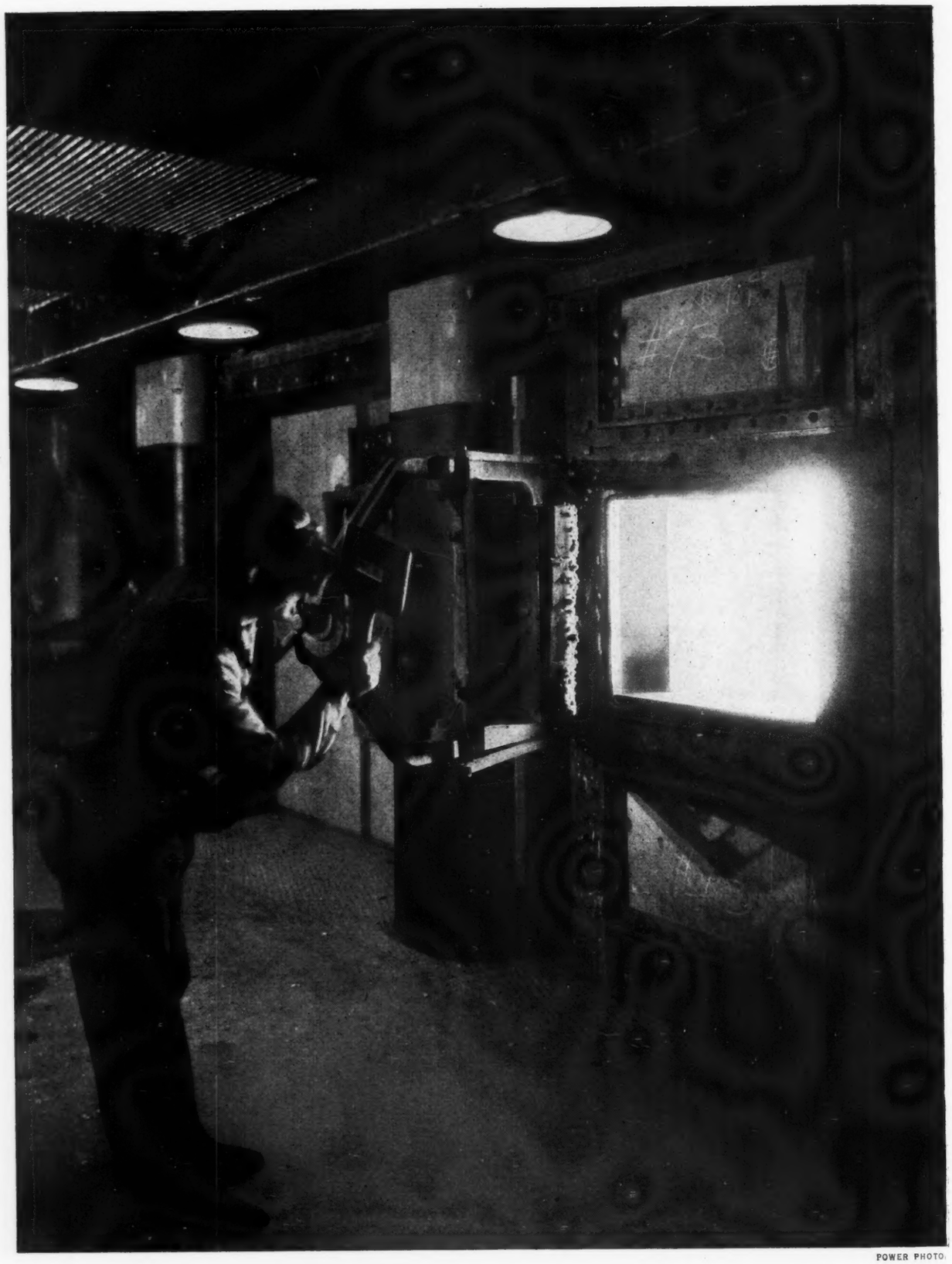




THE PLANT HERE SHOWN WAS ORIGINALLY DESIGNED TO HOUSE 400,000 KW. OF GENERATING CAPACITY. TODAY, WITHOUT CHANGE OF FLOOR PLAN, IT STANDS COMPLETED AS THE WORLD'S LARGEST STEAM-ELECTRIC STATION — CAPACITY 770,000 KW. NOTE THE GROWTH IN TURBINE UNIT SIZE FROM 50,000 KW. IN 1924 TO 160,000 KW. IN 1932.

SIMPLIFIED PLAN

OF HUDSON AVENUE



POWER PHOTO.

THERE IS NO RESTRICTION ON THE OPERATOR
OPENING THE DOORS TO OBSERVE THE FUEL BED

CONTINUITY AND ECONOMY DETERMINE OPERATING PROCEDURE

By BERT HOUGHTON
Operating Superintendent
Brooklyn Edison Company, Inc.

NO PICTURE of Hudson Avenue station is complete without a discussion of the development of the operating practices which have coordinated the equipment characteristics, the detailed analysis and solution of each successive operating difficulty, and cooperation among the personnel. The operating record shows that much more than the perfunctory generation of power has been accomplished. While carrying the load is the fundamental requisite of a generating station it is no longer the measure of successful operation, now based on the degree to which the personnel attain the minimum cost of kilowatt-hours sent out, in the face of conflicting requirements and handicaps. It is the degree to which refinement in operating analysis and procedure has been carried, that makes the story of operation at Hudson Avenue interesting.

Hudson Avenue station is the basic source of power for the Borough of Brooklyn and in addition, through interconnection with the other stations of the metropolitan area, it furnishes power to the Borough of Queens and to lower Manhattan. It is the chief source for power and light for the two and one-half million people in Brooklyn. Thus, the conditions under which the station is operated are very exacting as to continuity, frequency, voltage and load control.

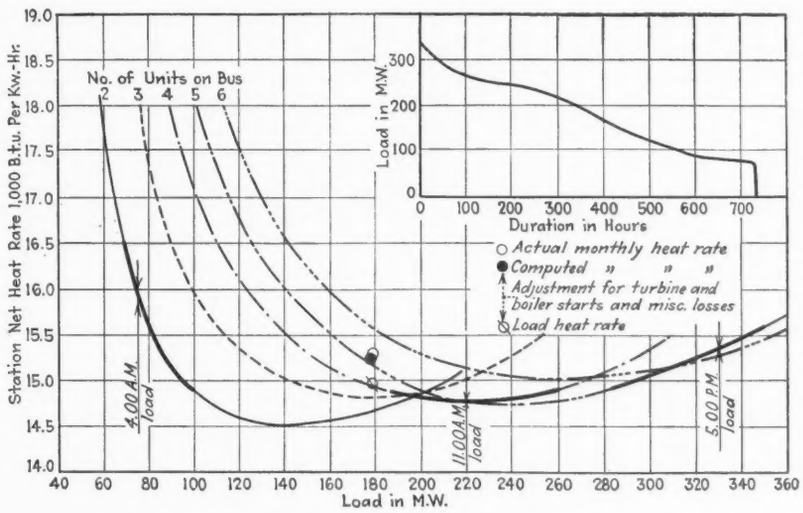


Fig. 1—Comparison of actual heat rates with those computed from equipment tests

Despite the difficulties presented, station heat rates have consistently approximated the results predicted by carefully conducted tests. This is brought out in Fig. 1, which shows a comparison of the actual station heat rates with the heat rates computed from tests on station equipment.

During construction of the original installation, the operating crew was gradually assembled at the station and was composed of men transferred from the Gold Street and Sixty-sixth Street generating stations, and from some of the substations. These men not only watched the erection of the equipment but studied the plans and connections so that when the time came to operate they were thoroughly familiar with the requirements.

The turbine units were larger than any single-shaft machines that had been built and the boiler units three times larger than any previously operated in our stations. The station layout, both steam and electrical was quite different from either of the generating stations from which the men were taken. The use of all electric drives for auxiliaries with the exception of one or two emergency drives and the remote location of the control for the auxiliary supply made necessary a much closer relationship between the men responsible for steam operation and those having to do with electrical operation than was required in other generating stations of the company. The station steam and electric services were no longer strictly independent functions but intimately associated at every stage in the generating cycle. This required bringing the men who were to supervise the steam operations and the electrical operations into close contact during the training period, so that they would become familiar with each other's problems. The operators readily grasped the new problems, and the ease with which Hudson Avenue was started and has since operated may be traced to this policy of always keeping the operating personnel in touch with the design and construction program.

However, the actual operation of the stokers which were much larger than any that had been handled previously required several months of study and experience before the best results were obtained. Improvement was most emphatically shown by the records of the original 300-lb. pressure boilers which started out at about 63 per cent efficiency and gradually approached 78 per cent. Fig. 2 shows the rapid improvement in boiler efficiency during the first years of operation of the original 300-lb. section. This efficiency curve has dropped off in latter years due to the increased number of banked boilers carried in this section. On the other hand, the efficiency of the 400-lb. section has increased during the past three years due to improved design and methods of operation. That it took several months to bring the operation of

these original stokers to their ultimate efficiency is not an isolated case, but with each new installation a considerable period was required to study the stoker characteristics and the influence of different coals before consistently high efficiencies could be maintained.

Operation has been one of steady evolution. Nothing was taken for granted, each practice was carefully analyzed and continued in use or discarded as the analysis dictated and accepted methods are continually scrutinized for improvement. A noticeable physical difference at Hudson Avenue, in comparison with other large stations, is the number and size of the observation doors in the boiler settings. Every part of the fuel bed may be conveniently and easily seen. There is no restriction on the stoker attendants opening these doors and continually observing the fuel bed. This continuous observation permits the attendants to see an incipient case of trouble and correct it before serious disturbance occurs. Despite our practice of carrying high overfire draft, the continual opening of the doors has negligible effect on efficiency. Where the doors are not used as frequently, it is quite easy to find large holes in the fire letting through much more excess air. In this connection it may be said that the control of the fuel bed should be sufficiently flexible to correct any tendency for unevenness, particularly with reference to the resistance of the various sections to the flow of air.

An important feature in economical boiler room operation is the control and reduction of maintenance cost, the principal items of which are maintenance of the stoker iron and refractory furnace walls. In attempting to improve the combustion processes the effect on efficiency of these maintenance features is often overlooked. It is evident that the furnace temperature must be held within the temperature limitations of the refractory if the maintenance of these walls is to be kept within reasonable figures; therefore temperature limitations of stoker operation apply to the fuel bed. The ash of many bituminous coals will fuse at temperatures found in the fuel bed. The plastic ash on being carried up by the products of combustion will form a hard slag on the comparatively cool boiler tubes. While this slag formation may be materially reduced by proper attention to the fuel bed, its accumulation on the tubes should be closely watched. The effect of slag and such accumulation is shown in Fig. 3. Here the temperature of the flue gas on each boiler is compared with the flue gas temperature as found under test conditions on clean boilers. Consideration is given the effect of excess air on the flue-gas temperature so that the effect of boiler cleanliness may be known. Boiler service hours and banked hours are also shown and give a better conception of the causes of boiler fouling.

To reduce fouling it was necessary to develop the fuel bed at Hudson Avenue, so that the temperature would be comparatively uniform over its entire area. Such uniform temperature means that combustion rates on the various sections of the fuel bed must be nearly equal; therefore a comparatively uniform quantity of air must be supplied to the various sections. Such air control might be accomplished by sectionalizing the wind box and controlling the air supply by small dampers or it might be accomplished by controlling the fuel bed contour with the fuel bed acting as a uniform resistance to the flow of air. This latter method was more practical and was found entirely satisfactory after the proper manipulation of the stoker controls was developed.

Investigation indicated that the release of volatile matter and the resulting coking of the coal should not take place immediately at the head of the stoker, but should be somewhat slower and be distributed over a suitable area. Also, the breaking up of the coke as it formed should not be too violent. More gradual coking with the more gentle shearing or coke breaking action, not only allowed time for the volatile to properly burn in the furnace, but also allowed the air from the tuyeres to permeate through the coal in the retort sections. This desired condition could best be obtained with a thin fuel bed. Since the wind box pressure increases with increasing fuel bed resistance it is obvious, that the necessary volume of air may be supplied to the stoker at a relatively lower pressure, provided a thin porous fuel bed is maintained. It is also readily understood that the coked surface of a thin fuel bed may be broken up with less violent action than the thick heavy bed and it is well known that the too rapid breaking up of the coking coal is one of the chief causes of smoke.

While it was at first regarded as desirable to limit as far as possible the air-to-coal ratio in order to reduce

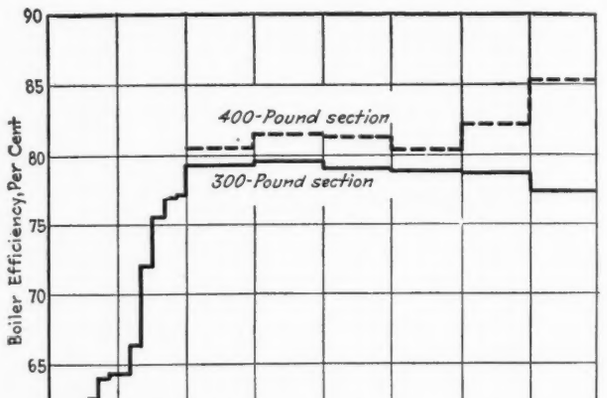


Fig. 2—Yearly boiler efficiencies, 300- and 400-lb. sections

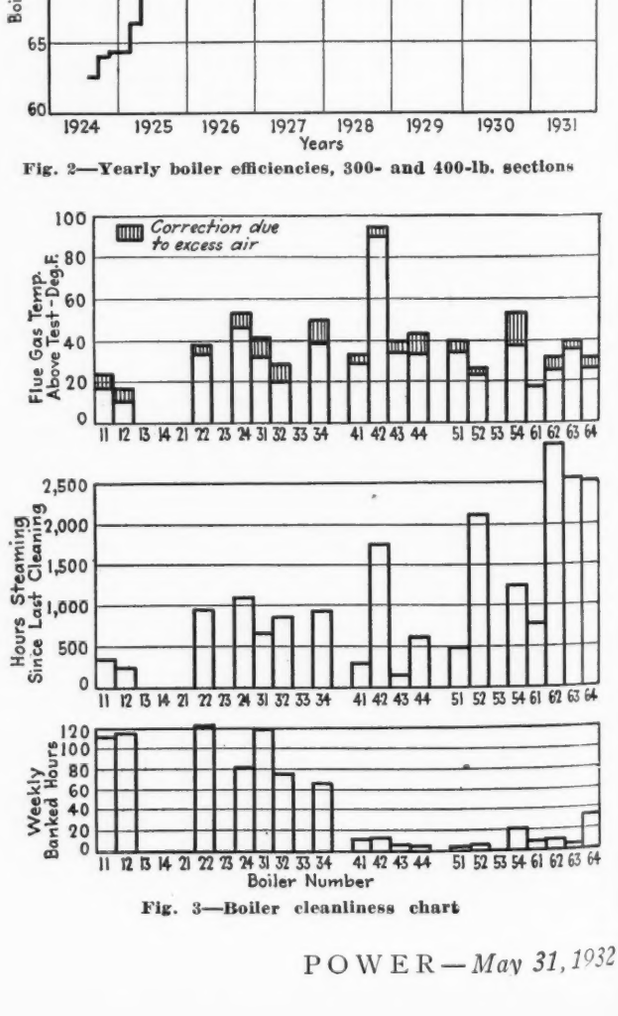


Fig. 3—Boiler cleanliness chart

the dry gas loss, it was found on further investigation that this could easily be carried to a point not consistent with best operating economy. Excess air is often controlled by the analysis of flue gas samples taken at the boiler outlet. The air-to-fuel ratio is then set at a point slightly above the minimum at which carbon monoxide will appear. Complete analyses of gas samples taken at the boiler outlet indicated that the usual Orsat analysis taken at this point was not a safe criterion of complete combustion. Moreover, the complete gas analysis at the boiler outlet was not necessarily indicative of the amount of unconsumed combustible at the furnace outlet since, as frequently is the case, combustible leaving the furnace will burn as secondary combustion in the tube bank and will not appear in an analysis at the last pass. The lower curve in Fig. 4 shows the loss due to CO in the flue gases as determined by the conventional Orsat. The upper curve includes losses due to the presence of hydrogen, and hydrocarbons, which could not be shown with the conventional Orsat. The vertical distance between the two curves represents hydrogen and hydrocarbon losses.

Another factor in the production of high boiler efficiencies is the use of fuels best suited to the particular furnaces. While bituminous coals, in general, have similar characteristics, the differences in their burning on underfeed stokers is often sufficient to make a change in operating practice necessary. The qualities of greatest importance are the ash content, the temperatures and conditions at which the ash will fuse and form clinker and the coking characteristics. In coking characteristics not only the character of the coke formed, but also the quality and behavior of the volatile matter should be considered. It is often found that coals having practically the same analyses, when burned on a stoker have altogether different coking characteristics. In one case, as the volatile matter is released and coking progresses, large porous masses of coke will be formed that are easily broken as the fuel moves down the bed. Another coal will form a dense coke which will require considerable pressure to break it sufficiently to allow proper air percolation. Still another will form a coke that will easily be blown from the grates and cause high cinder losses. Determination of the proper coal is most satisfactorily accomplished by bringing in test cargoes of a large number of coals which apparently have the desirable characteristics judged by their analyses. The final test of their fitness, however, should be made by actual trial on the stokers in question.

It was an old saying among power plant operators that the efficiency of the plant depended upon operations in the boiler room, that very little could be done in the turbine room to increase the over-all efficiency of the station. It was felt that if the condensers were kept clean and all joints kept tight, the maximum efficiency of the turbine room would be obtained as the turbine efficiency was practically determined by its design. While this is in a large measure true investigation of machine loading at Hudson Avenue indicated that material savings in station operation could be effected by a proper loading schedule.

The effect of turbine loading may be readily observed in Fig. 5. Here a comparison of heat rates has been made within the operating range of a group of turbines showing the savings that are made in the turbine room by dividing the load incrementally rather than by base loading. The unit heat rate curves in Fig. 6 would appear to justify putting more load on unit No. 7. In

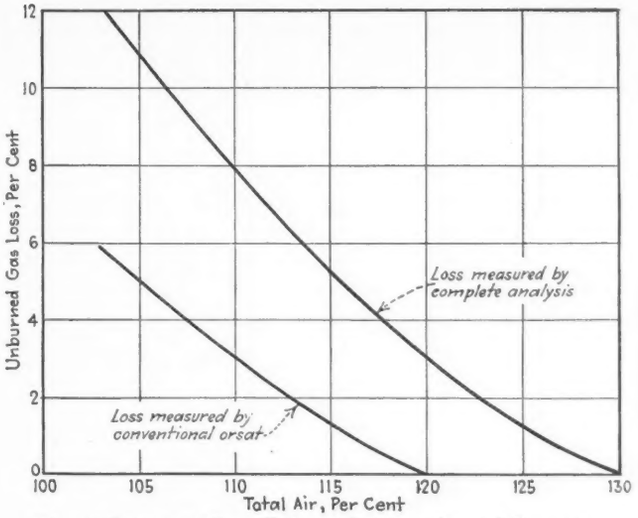


Fig. 4—Loss in boiler efficiency due to unburned flue gas

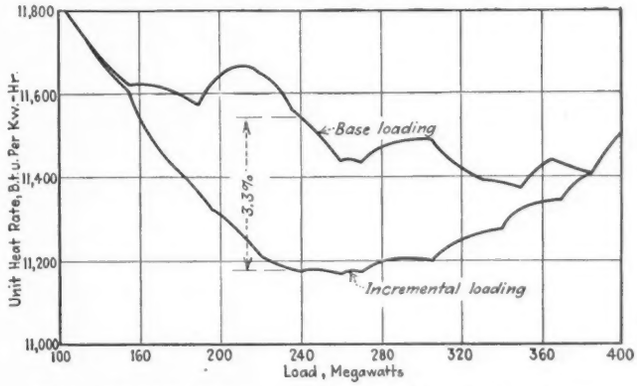


Fig. 5—Comparison of combined turbine heat rates—base loading vs. increment loading units Nos. 1, 4, 6 and 7 at 55 deg. cond. water temp.

addition to the saving indicated for the turbine room, there is also an added saving in the boiler room, both because of the reduction in steam required and because of the increased efficiency of the boiler room in supplying less steam. In general, the incremental method of loading boilers is also used and the combined effect of using this method in the turbine room and the boiler room has a material effect on the over-all station efficiency which is often not apparent from the monthly records of individual boiler efficiencies or turbine heat rates. While it has required considerable time and energy to obtain the necessary data and make the necessary calculations for setting-up accurate loading schedules, it has been one of the outstanding items in improving over-all station efficiency and in approaching the test characteristics.

After the first units had been put in operation in 1924 there were three important steps in increasing station performance to a comparatively economical basis. One of the first was to develop stoker operation so that the fundamental requisites of furnace efficiency could be attained. These requisites were recognized as a regulation of the combustion processes on the stoker so that combustion would be complete at the furnace outlet, the ash-pit loss comparatively negligible and the stack loss as low as the boiler design would permit.

It was, of course, necessary to have all instruments properly calibrated so that accurate data on each day's performance could be obtained and analyzed in order to determine the various boiler losses. It was also of

equal importance to establish "bogies" for the various boiler losses by the performance of tests under best operating conditions so that the operating force would have a clear conception of the efficiencies to be attained. Fortunately the station layout was such that accurate tests were possible without resorting to elaborate temporary test setups. Permanently installed weigh tanks for weighing main condensate, boiler feedwater, etc., also volumetric tanks for accurately measuring the turbine bleed condensate, together with the necessary test pumps, test piping, the proper isolation valves, thermometer wells, and test pressure connections were of great

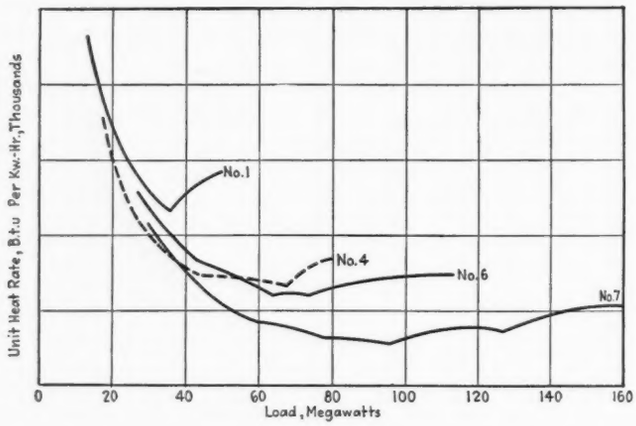


Fig. 6—Turbine heat rates, units No. 1, 4, 6 and 7 at 55 deg. circulating water temperature

assistance in establishing the "bogies" under the normal operating cycle.

In regular operation the performance of each boiler, main unit, etc., was checked daily. A complete report was made up daily, weekly and monthly. In order that the information obtained should be put to immediate use, a daily meeting was instituted to discuss the result of the previous day's operation. This meeting was attended by the Station Superintendent, Chief Engineer, First Assistant Chief Engineer, Chief Boiler Room Engineer, and Station Test Engineer. The latter, who prepared the record of performance, was in a position to point out any deviations from the test performance of any piece of apparatus. The others were able to explain any unusual operating conditions and to initiate measures to restore the performance to its proper level.

It was at first thought advisable to make a particular study of the losses and to determine the boiler efficiency by the loss method, using an estimated figure for radiation and unaccounted for losses. It was pointed out that such a method should be satisfactory under normal conditions and that it also eliminated the extremely high or low efficiencies which appeared when the boiler was either taken off or put on the line. In actual practice, however, it did not work out well. Its worst feature was that it indicated the boiler efficiencies to be higher than actual. Such a condition gave to the boiler operating force a complacent feeling. They were apparently maintaining in actual operation, efficiencies as good and in many cases better than the bogies set up under test conditions. The principal cause for such a situation was, in the arbitrary percentage used for the radiation and unaccounted-for losses. Fig. 7 shows a group of radiation and unaccounted-for loss percentages for a number of different stations at various ratings for stoker-fired installations. A study of this figure shows that these radiation and unaccounted-for losses vary widely so that it is not good practice to assume these losses in the heat balance. Subsequent station performance has been based on direct measurements of fuel and water, with frequent calibrations of the instruments used.

One of the main contributing factors in maintaining efficient operation has been the use made of the various instruments as operating guides. Success was attained only after it had been proved that the instruments were really as valuable as claimed. The most complicated of these guides was also the one most difficult to calibrate and maintain in such condition that its indications were of value rather than misleading. It was only after several years of intensive development work in coordinating the characteristics of the boiler flow-meter that complete confidence was established in its indications. The details of this work have already been published in the A.S.M.E. proceedings.

The degree of success attained in the operation of Hudson Avenue is fundamentally a reflection of the interest and cooperation of the attendants. Each man has been schooled not only in his own work and that of his immediate associates but in the functioning of the entire station. This has developed not only a localized skill but a pride in the station performance as a whole and has awakened a realization in each individual that it is only by cooperation that the best results may be obtained. A most important condition affecting the daily efficiency has been getting away from the old time rivalry between the successive watches in producing individual boiler room records at the expense of the succeeding watch. This attitude at times manifested itself by burning down fires to too great an extent during one watch thus requiring the succeeding watch to

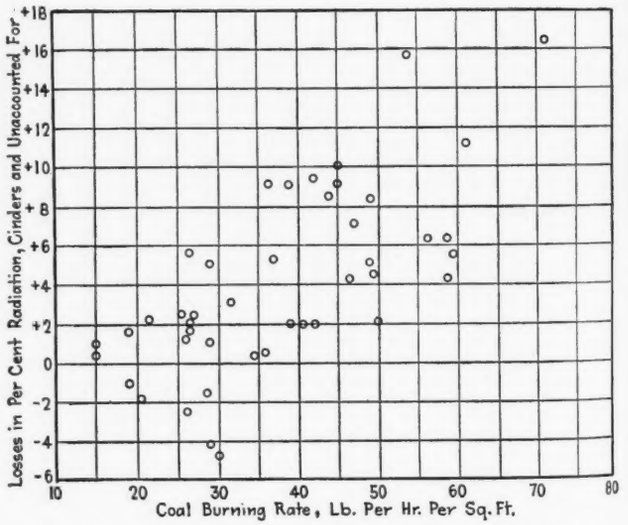


Fig. 7—Radiation and unaccounted for losses in several stoker-fired installations

rebuild the fires to replenish the coal which had been improperly used. Not only was this practice unjust but actually resulted in poor fire conditions and lower twenty-four hour efficiency. It placed the watch efficiency on the basis of personalities rather than on its true basis. One factor in modifying the undesirable features of watch rivalry, while still retaining the good features, has been rotation of the supervisory forces from watch to watch and in some cases the immediate

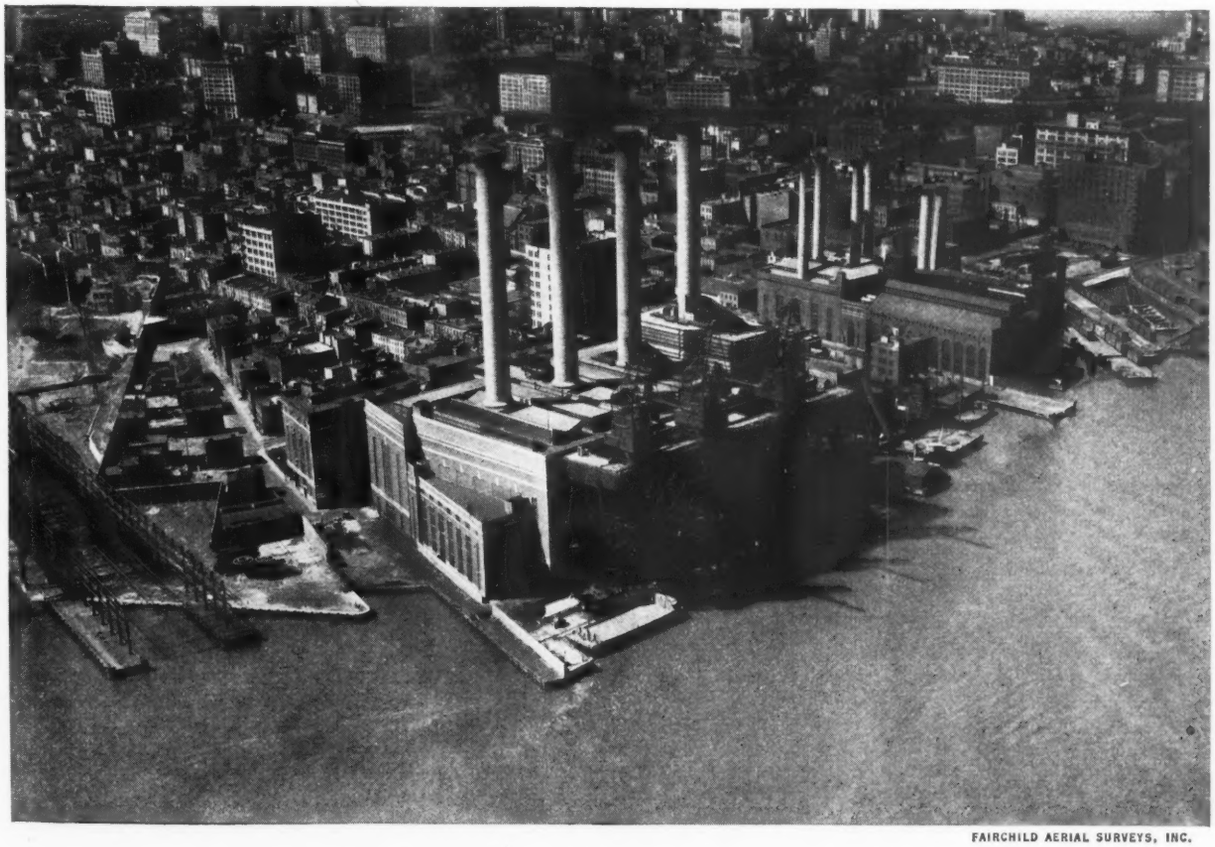
attendants. In this way the men become familiar with the complete daily cycle of operation. They learn not only what is required of each succeeding watch, but also the correct operating characteristics, particularly of the stokers, for all ranges of operation. They are therefore able to anticipate the conditions with which the succeeding watch must cope. Continuity of efficient operation is thus effected which was impossible when the personnel of each watch was fixed from year to year and operated practically independently.

The problem of operation versus design is of a cyclic character. Operation must suit the design but at the same time succeeding design is very much modified by the operating requirements. The original design of Hudson Avenue was essentially influenced by the operating requirement of utmost reliability and the necessity for using equipment that had passed the pioneer stage. As the station developed, and particularly when interconnections were accomplished there was more opportunity for installing equipment of an experimental character. This was particularly true of the fourth unit on which a great deal of stoker and superheater development was accomplished. The difficulties that cropped up in the operation of the fourth row of stokers were capitalized in the improved design of the stokers for the fifth row of boilers.

Likewise, the difficulties in steam distribution in the superheaters of the fourth row which resulted in losing sufficient superheater tubes so that these boilers could not be depended upon, were capitalized in the development of the superheaters for the fifth row of boilers. Furthermore, the difficulties resulting from the preheated air equipment of the fourth row were capitalized in the development of the heat balance for the fifth row. As a result of this development work the fifth row and its duplicate the sixth row of boilers are very dependable, highly efficient units.

Further examples might be shown in the development of cinder catchers. The comparatively poor efficiency shown in the dry type of cinder catchers in the fourth and fifth rows of boilers led to a highly efficient wet type of cinder catcher for the sixth, seventh and eighth rows of boilers.

It has been the purpose of this article to outline the major features in methods of operation that have not only assisted in improving the design of each succeeding unit installed, but also have contributed to the economical basis on which Hudson Avenue operates. These improvements have been largely due to the coordinated efforts of the personnel of the station. Enthusiasm, good fellowship, cooperation and pride in accomplishment are the fundamentals on which successful operation is based. All of these will be found developed to a high degree at the Hudson Avenue Station.



FAIRCHILD AERIAL SURVEYS, INC.

AERIAL VIEW OF HUDSON AVENUE STATION, BASIC SOURCE OF POWER FOR THE BOROUGH OF BROOKLYN

THE ENGINEERING ASPECT OF EQUIPMENT PURCHASING

The equipment proposals of manufacturers are evaluated by the engineers without consideration of price. With these evaluations in hand the Purchasing Department makes price comparisons

By J. N. LANDIS
Mechanical Engineer
Brooklyn Edison Company

BROOKLYN EDISON'S organization for selecting mechanical equipment consists of mechanical engineering, operating, and purchasing departments, each with well-defined and coordinated responsibilities. The engineers prepare specifications which are transmitted to the manufacturers by the purchasing department. The manufacturers confer with the purchasing and mechanical engineering departments while preparing their proposals, then send these without prices to the purchasing department, which refers them to the engineers for analysis. The engineers, without knowledge of price, report to the purchasing department their money preference for the different proposals compared to the most advantageous proposal as par. The purchasing agent, by combining the engineers' evaluation and the manufacturers' prices, which he has received separately, determines the buying preference.

Evaluation by the Engineers

The basic reason underlying evaluation is a willingness to pay for advantageous qualities. Consequently all the elements of advantage and disadvantage in a proposition must in the final analysis be expressed in dollars. This evaluation is regarded as the problem of the engineers, likewise the defense, if such is needed, at the time representations on the matter are made to the executives.

Because of the significance of compound interest, a dollar of operating cost in say the ninth or tenth year after purchase could be paid for by about half the sum deposited at the time of purchase and allowed to grow at compound interest. Therefore, in comparing annual costs with purchase costs, the engineers reason that the annual costs for such items as coal, maintenance, taxes, and insurance during the life of the equipment have to be converted to what they term "purchase date equivalent values." This conversion is effected by dividing any charge in the year "n" by the compound interest factor $(1 + e)^n$, where "e" represents the earning rate of money invested in the Company. The sum of all the "purchase date equivalent values" of annual operating costs can be compared with purchase costs.

The underlying principle followed in all specification writing and equipment purchasing is to buy a complete workable piece of apparatus to produce results. In no case are we to accept a bid or recommend a purchase of equipment expecting later to modify it and make it workable. The engineers are instructed that during the process of a negotiation they should consider it their duty to the company and in the general interest of the development of the art to go back to any manufacturer with criticisms of faults which transgress well-recognized principles of design and also to suggest the desirability of incorporating features which might easily enough occur to any skilled designer. These suggestions are offered in such a way as to avoid the company's assuming the base constants involved in the equipment design or other responsibility for the manufacturer's products. Where the extent of such suggestions substantially involves a re-design, it is felt wise to keep hands off, as the company is not engaged in the business of general machine or equipment design.

All the foregoing has reference to developed apparatus. When, on the other hand, a need exists for which there is no source of supply, we become co-partners with the manufacturers, and follow an entirely different procedure. The manufacturers are informed of our requirements, given suggested means of achieving them, their designs criticized, and the company assumes a measure of responsibility for the resulting product. Such instances are rare, and in these few cases the development is carried on simultaneously with a plurality of manufacturers.

Generally, specifications are worded so that the utmost freedom is permitted the bidders in working out their propositions. Thus, for the Nos. 7 and 8 row boilers the specification avoided any statement of desire for a cross-drum straight-tube boiler or for a bent-tube boiler, and made no mention of the extent of heating surface or desired exit gas temperature and other related details. Instead, a definition was made of the space available for the equipment and as to the money value of efficiency at different outputs.

If in working out his best proposition the manufacturer found he could afford to keep on enlarging the boiler until it completely filled the allotted space, then that consideration determined the right size of equipment to offer; if he found that before he filled the space he reached a point where a further increase of size would cost more than the resulting improvement in his evaluation, that condition determined his economic size. We regard it as very important that the manufacturer should seriously use the specified evaluation system to determine the best type and the most economic size of equipment to offer in order that he not be at a decided disadvantage compared to the manufacturer who does follow through the prescribed system.

While the manufacturer is preparing his proposition, and after he has submitted it, the purchasing department gives him every opportunity of discussion with the engineers in order that he may completely understand the specification and that he may present his design to the fullest advantage. In all these contacts with the manufacturers we sedulously avoid any possible interpretation of our action as a process of trading the private information of one manufacturer to another.

Working With the Manufacturers

Helpful suggestions are frequently made by the manufacturers after the specifications are issued. When it is desired to incorporate these in the work, revisions to the specifications are made in the form of addenda sent out to all bidders. As illustration, the original design of the boiler house for the two 160,000-kw. new units included two steam-generating units on the dock outside the existing building. When one bidder thought he could supply the required steam without dock boilers, an addendum to the specification was issued which said: "A value of 4,480,000 kilo.-B.t.u. per hour total output of eight boilers inside the existing building would be very attractive, entirely contingent on layouts and details, as making consideration of elimination of dock boilers possible." The equipment was installed on this basis.

Salesmen often attempt to convince us of the large margin of safety in their guarantees with the evident hope that some or all of this safety margin will be added to their guarantee at the time of making the evaluation. When the manufacturer will not back up his salesman's talk by committing himself definitely in his guarantee, such sales talk is wasted effort, being ignored entirely.

I wish to compliment the manufacturers on the high type of engineering and salesmanship devoted to the preparation and presentation of proposals. Our great respect for the ethical salesmanship common to the industry is only intensified by an occasional encounter with the snooping type of salesman whose principal interest is in the details of his competitors' bids. We attempt to keep the purchaser's attitude on a plane equal to that of the finest of the bidders.

After receipt of manufacturers' proposals, it is desirable to prosecute the work of evaluating the guaranteed performance as quickly as possible. To this end the operation has been reduced to as nearly mechanical a form as is consistent with the complexity of the proposition. The comparison of two alternate pump proposals can be accomplished in a few hours by a man familiar with the procedure, while the comparison of two condensers may take two men several days. Continued study of practical methods of carrying out these evaluation principles has reduced the time and labor requirements to about one-tenth of our early experiences without a sacrifice in the significance of the work done.

It must not be believed that the system of equipment selection described reduces merely to computing an answer from manufacturers' guarantee values substituted in a formula. In addition, very careful investigations of the mechanical design features are conducted. We appreciate with profound respect the amount of information which can be obtained by taking trips to other stations to interview those who have had operating experience with the same or similiar equipment.

In order to benefit from the long practical experience of our operating department, it is regular practice to send each equipment proposal to them for study and comment. The practical investigations have a very important bearing on the selection of equipment. Finally, the tabulations of charges for the purchasing department to apply to the different proposals is based on the evaluation of the quantitative guarantees plus the combined views of the engineers and operators on those elements of the proposals which have to be evaluated by application of judgment. Generally, the guarantee evaluation predominates in the evaluation total on equipment carrying a quantitative performance guarantee.

The actual selection of equipment is a result of the combination of the evaluation charges and the prices. Of course, the selection is tempered by considerations of purchasing policy, such as the dependability of shipment promises, the time required for manufacture, the reputation of the manufacturer for fairness and the encouragement of active competition.

After a contract is awarded the progress of design, fabrication, and erection of the equipment is closely followed by the engineers and the construction inspectors until it is ready for operation. A reasonable period of preliminary operation is expected, during which checks on the performance are made to establish that the equipment is functioning properly; then the acceptance tests are made.

Acceptance Tests Regularly Made

A definite policy of checking the performance guarantees by acceptance tests is regarded as essential to any process of buying on an evaluation method which places a high premium on attractive guarantees. We expect that when equipment is installed it will meet its guarantee or that the manufacturer will stick to the problem of correcting it entirely at his own expense until it does. Our whole philosophy of acceptance of guarantee is based on dealing only with responsible manufacturers who will make their commitments good if the acceptance tests show that guarantees have not been met. Our experience in this connection thus far where occasionally a guaranteed result was not obtained has been very satisfactory, the manufacturers modifying their equipment even at considerable cost.

Proving that the guarantee has or has not been met requires the performance of an acceptance test of such accuracy as cannot reasonably be disputed. We have installed very adequate facilities in the basic station design for acceptance testing and for routine operating check. For the conduct of acceptance and other special test work, the research bureau of the executive department maintains a competent test organization. This test division has been several times complimented by different manufacturers for having furnished them from tests in Hudson Avenue station some of the most complete and accurate performance data available in the country.

System in Use Since 1922

The equipment evaluation system described above has been used in one form or another since 1922. During this period it has undergone a gradual evolution until it has become a plan which is executed with thoroughness and considerable dispatch. Its use has promoted a consistency of engineering and purchasing practice over the ten years which would be hard to excel. We do not know of any other plan of selection and purchase which we think would result in as fair judgment of all phases of the work and as satisfactory overall experience during negotiation and operation.

INSTALLATION PROBLEMS

SCHEDULING—STORING HANDLING

With practically no space for storage of arriving shipments, the 320,000-kw. extension of Hudson Avenue Station was completely erected in 18 months

By J. E. WHALLON
Mechanical Construction Engineer
Mechanical Engineering Dept.
Brooklyn Edison Company

THE EQUIPMENT for Units No. 7 and 8 was purchased on the basis of erection by the manufacturers or their contractors. Construction was preceded by the preparation of a detailed schedule which took into account the time required for the different steps of preparing specifications, conducting negotiations, approving drawings, fabricating and delivering equipment, and erecting it. This installation was larger, of greater complexity, and more closely fitted into the contour of the existing structure than any previous installation.

Since the building occupied practically all the station site and since the equipment for these two units completely filled the building, there was no appreciable space for storage of construction materials. Therefore from the very first the essence of the construction problem was one of coordination and timing to keep material moving from the shops to its final location in the station. For example, steel supports and foundations had to be completed in advance of equipment arrival or the equipment could not be received for lack of other space to set it down.

Coordination of Departments

Meetings were held every two weeks in which the progress of each phase of the work was reviewed and coordinated by the electrical engineering, mechanical engineering and purchasing departments. The actual field work of the various contractors was coordinated and inspected by the three construction bureaus concerned, respectively, with building, electrical and mechanical features. These groups maintained close daily contacts. Since there were as many as eighteen contractors on the job simultaneously, engaged in closely interrelated work, it was imperative that the field bureaus see to it that each contractor carried out his particular part on schedule in order that others would not be delayed.

When erection of the structural steel supports for the boilers started on Nov. 10, 1930, drums, tubes, heaters, economizers, turbine parts and other equipment were in process of fabrication in various shops throughout the country. The first drum for No. 71 boiler arrived on Nov. 28, immediately after completion of the supports. From this date until all major parts of the two units were installed and operated, on May 3, 1932, there was almost unbroken series of deliveries.

Most of the boiler house material was lightered from New Jersey and Staten Island terminals to a slip at the west side of the station property. Frequently as many as three lighters per 8-hour day were unloaded at this point, making it essential that the railroad terminals be kept advised so that empty lighters could be removed and loaded lighters put in place almost to the minute. Some congestion on the wharf and in the building was unavoidable.

The larger pieces of equipment for the turbine room could not come into the slip at the west end of the station because there was no way to get parts of such size from the dock through the boiler house to the turbine room. Fortunately the company was able to lease a small part of the Brooklyn Navy Yard directly east of the station. This permitted landing turbine and condenser sections near the site. These were then trucked or rolled from the Navy Yard through the street the full length of the station into a door at the west end of the turbine room, whence they were handled by crane.

Pipe work provided one of the major problems. Before the start of the work every effort was made to lay down an ideal piping schedule and to insure early delivery of the 24-in. main steam and 14-in. boiler-feed materials by purchasing the piping, fittings, and valves for these lines well in advance of placing the general piping contract. Part of this material had been erected and shipments were being received daily when work was stopped due to the discovery that some of the seamless tubing was defective. A 16-in.-diameter bent pipe burst open for a length of four feet at a pressure only 100 lb. below the required test pressure of 1,500 lb. At the break there was only $\frac{3}{8}$ in. of good metal, compared with the $\frac{3}{4}$-in. nominal wall thickness required. In addition to the actual rupture, a crack approximately six feet long extended almost through the wall thickness of the tube diametrically opposite the rupture. Ensuing examination of other seamless tubing over 10-in. diameter resulted in rejection of the entire lot, so that such piping as had been erected was taken down.

Because of the long time required to manufacture new tubing it was approximately five months later than originally scheduled that replacement main steam and boiler-feed material arrived on the job. This condition necessitated radical changes in schedules and resulted in placing the No. 7 machine in operation about three and one-half months later than originally intended. The No. 8 machine operated as scheduled.

Within a building space originally intended for 100,000 kw. of capacity 320,000 kw. has been erected in a period of eighteen months. This installation constitutes probably the most compactly arranged power plant exclusive of marine installations. The various elements have gone together with remarkable freedom from interference and major trouble. Great credit is due the manufacturers' field men for their fine spirit in working together so harmoniously on such a complex job. The success of work is the direct result of detailed planning and earnest cooperation all along the line.

STATION HEAT BALANCE

The diagram shows the three different arrangements utilized. All are relatively simple and excepting four steam-driven boiler-feed pumps all auxiliaries are motor driven

STEAM pressures at Hudson Avenue are moderate. The first three units operate at 265 lb. pressure and the remaining five at 400 lb. pressure. The increased operating pressure of the latter permitted higher feed temperature entering the boiler than was possible with the first three units. Changes to obtain higher feed temperature in the 400-lb. section was justified by eval uation of the cost and improved plant efficiency.

The heat balance for the first three units involves two stages of feed heating with steam bled from the main units. No economizer or air preheater are provided. With this section of the plant, two house turbines were installed that exhaust to condensers through which, when the house turbines are in operation, the main condensate is circulated before going to the low-pressure heaters. It has been found economical, however, not to operate the house turbines, power for station auxiliaries normally being obtained from house transformers operating from the high-tension bus.

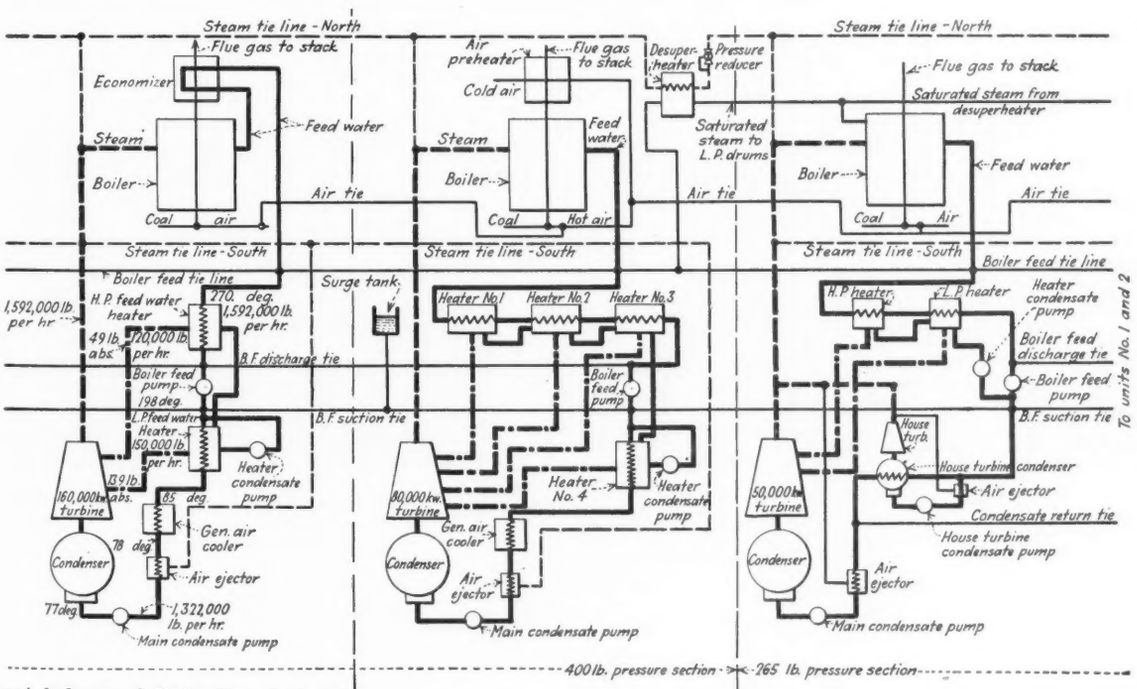
When the station steam pressure was increased, four stages of feed heating with bled steam and air preheaters gave definitely the most economical heat balance for the plant conditions existing when No. 4 unit was installed. This installation has proved satisfactory except for boiler house ventilation difficulties resulting from the presence of large hot-air trunk ducts above the boilers and below the boiler room operating floor.

Because of the undesirable features of the hot air duct layout on No. 4 unit, No. 5 was installed with economizers and two-stage bleeding, although studies showed the No. 4 arrangement the more economical. The No. 5 installation proved so satisfactory that the same heat balance arrangement was carried out for units No. 6, 7 and 8.

In all of the units in the high-pressure section condensate passes through air ejector condenser, generator air cooler and low-pressure heater before going to the boiler-feed pumps. All low-pressure heaters raise the temperature of the water to about 200 deg., it being necessary that this temperature be held down below the boiler-feed suction header vaporizing temperature, which is fixed by the location of surge tanks that float on this header.

For simplicity only one surge tank is shown on the diagram, whereas there is actually a surge tank for each unit of the high-pressure section and one for the first three units of the station.

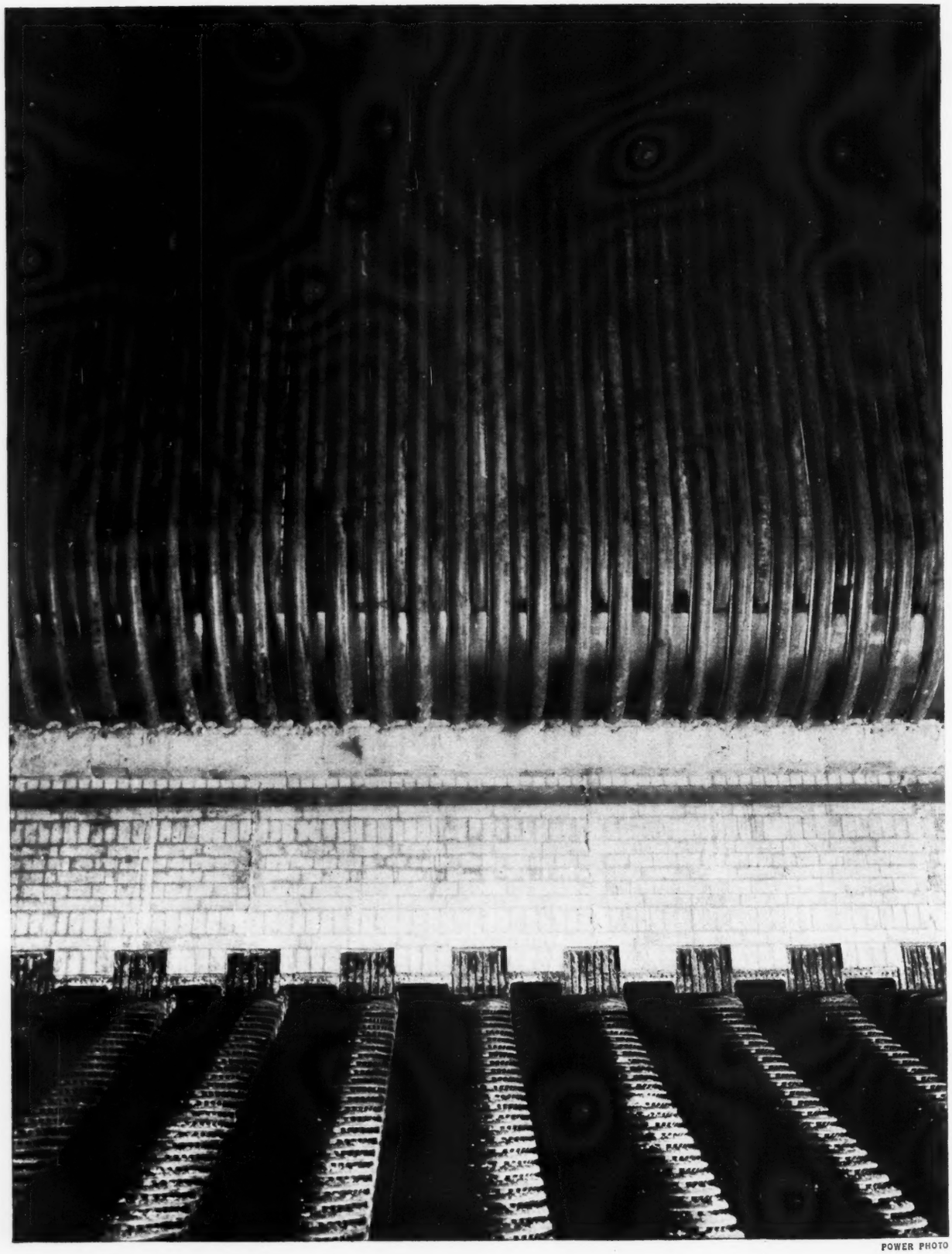
There are three 45,000-gal. city-water storage tanks. Make-up water from the storage tanks flows to the condenser shell under the control of a float in the surge tanks. Overflow from the surge tanks flows back by gravity to the storage tanks.



Typical heat balance of Units Nos. 5, 6, 7 and 8. Temperature, flow and pressure data refer to Units 7 and 8

Heat balance of No. 4 Unit

Heat balance typical of Units Nos. 1, 2 and 3



POWER PHOTO

FOUR WATER-COOLED WALLS BOUND THE FURNACES
OVER THE WORLD'S LONGEST UNDERFEED STOKERS

BOILER DESIGN

AN ACHIEVEMENT IN SPACE UTILIZATION

From start to finish Hudson Avenue station uses four boilers to serve each turbine unit. The column spacing of the boiler room fixes this requirement and allows no more floor space for the later boilers serving 45,000 kw. each than for the original boilers serving 12,500 kw. each. This article also describes briefly the feed pumps

▼

THE FLOOR PLAN at the Hudson Avenue Station, as originally laid out in 1922, provided for eight turbine units of 50,000 kw. each, with four boilers serving each turbine. When the station building was extended in 1925 and 1926 the building was completed to cover the ultimate limits of the station property, and the same arrangement and spacing of columns was maintained in the boiler room as for the original design. Since the building designed utilized the interior columns as supports for the overhead coal bunkers and as wind-bracing members for the building structure, as well as for supports for the equipment, the location of these columns was definitely fixed before detailed consideration was given in 1930 to the exact equipment layout which would occupy the space for the last two rows of boilers in the station.

Today we find that the completed station, without expansion beyond the walls originally set to include 400,000 kw. capacity, contains 770,000 kw. capacity. Each boiler in the first installation had a steam output equivalent to 12,500 kw. Each of the latest eight boilers is guaranteed to have an output of 520,000,000 B.t.u. per hour, corresponding to 45,000 kw. and an output of 610,000,000 B.t.u. per hour for two-hour peak loads. The boiler units immediately preceding this installation have an output of 385,000,000 B.t.u. per hour each. This growth in boiler unit capacity within the given column spacing was an engineering achievement reflecting the progress of the art of steam generation.

Each of the 160,000-kw. turbines requires 1,500,000-lb. of steam per hour at peak load. The corresponding boiler-unit capacity required is 500,000 lb. per hour assuming one boiler in each row out of service and 430,000 lb. per hour assuming all boilers but one of the eight in service.

The clear space between columns, measured in the direction of furnace width and at right angles to the river front, is 28 ft. 6 in. The center-to-center spacing parallel to the river front is 22 feet 6 inch.

Bent Tube Multi-Drum Boilers Selected

All boilers up to and including those for unit No. 6 were of the cross-drum straight-tube type. For units No. 7 and 8, boilers of both cross-drum and bent-tube multi-drum types were considered. Paramount consideration was given to increased stoker area for greater coal-burning capacity and to increased furnace height for improved combustion conditions. Propositions covering both types of boilers were worked into shape to meet these requirements and at the same time to leave the necessary space for operating aisles, tube removal and for boiler accessories. The boilers purchased were of the bent-tube multi-drum type, with separate dry-steam drum. The accompanying cross-section, as well as the general boiler room cross-section on page 790, shows clearly the more important measures taken to push the boiler proper "up and out."

First it will be noted that the roof extension structure is higher for the new units, making room for cinder catchers above the boiler room proper. The space the cinder catchers would have occupied if the arrangement in No. 6 row had been followed is thus made available for the economizers. Into the triangular space opened up by this shift of economizer position are fitted the three upper drums of the boiler.

Furnace Volume of 14,000 Cu.Ft.

The unusual shaping of the tubes in the outer bank leaves just the aisle space required for equipment and operation at the various levels. The use of water walls on four sides of the furnace saves space by reducing the amount of boiler-heating surface required.

Thus the boiler design is entirely special, although most of the construction details may be called standard for a boiler of this type.

This boiler design made possible an increase in furnace volume from 8,000 to 14,000 cu.ft. By extending the stokers and furnaces beyond the building column lines at the front and rear of the boiler the stoker area was increased from 524 to 694 square feet.

Water Walls on Four Sides

The heating surface, of 24,450 sq.ft., is composed of 3-in. No. 8 gage tubes. The three main boiler drums are 54 in. diameter, of riveted construction, with $2\frac{1}{2}$-in. thick plates. The dry drum is of the same construction, but of 48 in. diameter and with 2-in. plates.

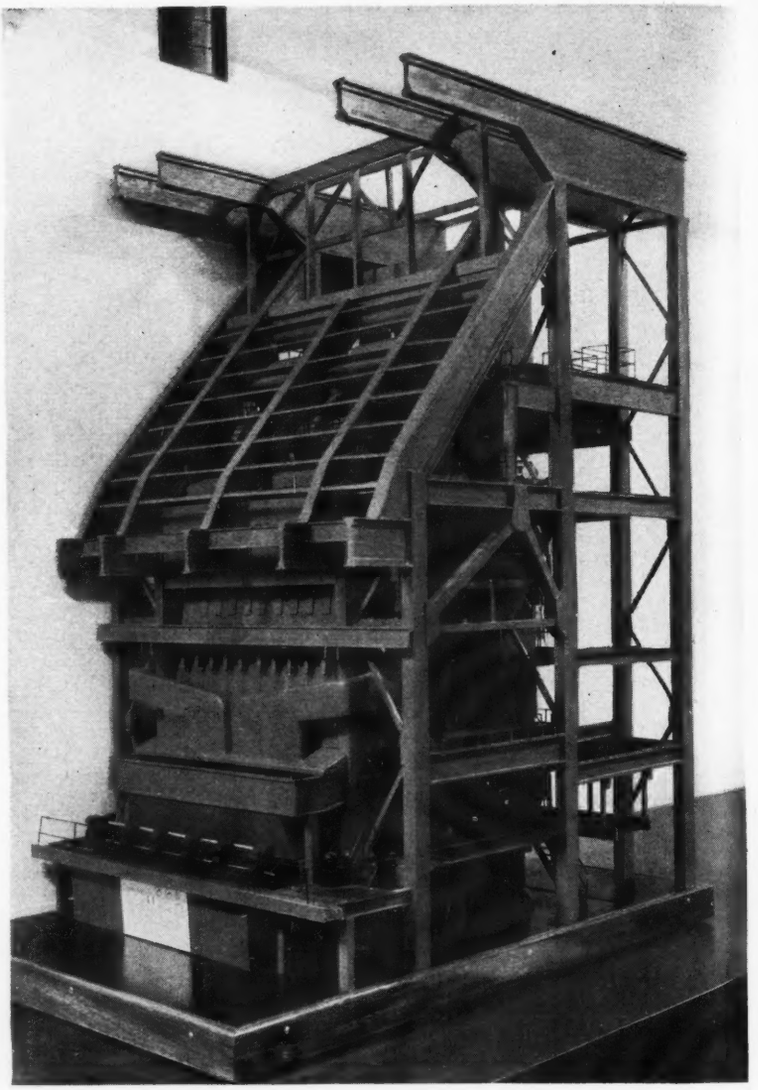
The front furnace wall is water-cooled except for a 4-ft. high brick wall above the stoker at the front. This is faced with silicon-carbide brick. Above it are 3-in. water-wall tubes on $3\frac{3}{4}$-in. centers. Alternate tubes have $\frac{5}{8}$-in. fins on both sides, providing 100 per cent metal surface. The rear wall is 100 per cent water-cooled and is made up of 4-in. tubes on $6\frac{1}{8}$-in. centers. In the ashpit and up to one foot above the fuel line these tubes are protected with iron blocks cast on the tubes. Above this line the tubes have 1-in. fins welded to both sides. These tubes discharge into the mud drum.

The side walls have the same construction as the rear walls from below the stoker up to an intermediate header at the mud drum level. This header delivers the steam and water to the upper front drum through 3-in. risers located in the furnace in front of a firebrick wall. The total water-wall heating surface is 3,846 square feet.

Numerous furnace observation doors give an excellent view of all parts of the fuel bed. Seven doors in each side of the boiler casing provide convenient access to all parts of the boiler section requiring maintenance or inspection.

Four pairs of soot blowers are installed in the interdeck space behind the superheater. The alloy elements are supported by alloy brackets welded to the boiler tubes.

The eight economizers (one per boiler) have 22,400 sq.ft. of heating surface each, composed of horizontal tubes with vertical lengthwise fins. Flanged return bends with metal-to-metal gasketless joints are used at one end of the elements. The other ends are joined by screwed and welded return bends. No soot blowers are installed on these economizers, because it was found on previous economizer installations that washing the gas surfaces with water when the economizer is out of service more effectively removes the particular type of deposit experienced with the coal used.



The modern large boiler, rising through several operating levels, cannot be seen as a whole except in a model such as this replica of the new Hudson Avenue units

A superheater of 5,740-sq.ft. surface, designed for 750 deg. F. superheated steam temperature at maximum rating, is installed in each unit. The elements are disposed within the first bank of tubes and are held in place by alloy clamps, but supported from the headers located above the upper front drum. The inlet header is supplied with steam at the center from two collecting headers, which, in turn, receive their steam from the dry drum through $3\frac{1}{2}$-in. delivery tubes. Leaving the two ends of the superheater outlet header, the steam passes through a motor-operated stop valve in each of the branch leads. A single non-return valve is installed near the main steam header after the branch lines join.

The feed water to each boiler is controlled by two regulating valves and two constant-excess-pressure regulating valves. One of the boilers is provided with a means of maintaining in the boiler a lower water level at low loads than at high loads. Because of the satisfactory results of this type of operation on this boiler it is intended to provide the same method of feeding on the remaining seven boilers.

Several departures from standard practice were made in the boiler accessories. Standard practice on blowoff valves would have dictated two pairs of valves for each water-wall header and four pairs for the lower mud drums. Water treatment at Hudson Avenue produces a very small amount of sludge, most of which is deposited more or less evenly on all tube and drum surfaces, with little settlement. Blowoff valves are therefore used primarily for draining purposes, with an occasional blowdown operation to reduce the concentration of dissolved solids.

For this reason two pairs instead of four pairs of blowoff valves are connected to the mud drum. Each lower water-wall header has one blowoff connection with one valve at the header. The drain lines from two headers are tied together and a single valve placed in the common line. This arrangement gives ten instead of a

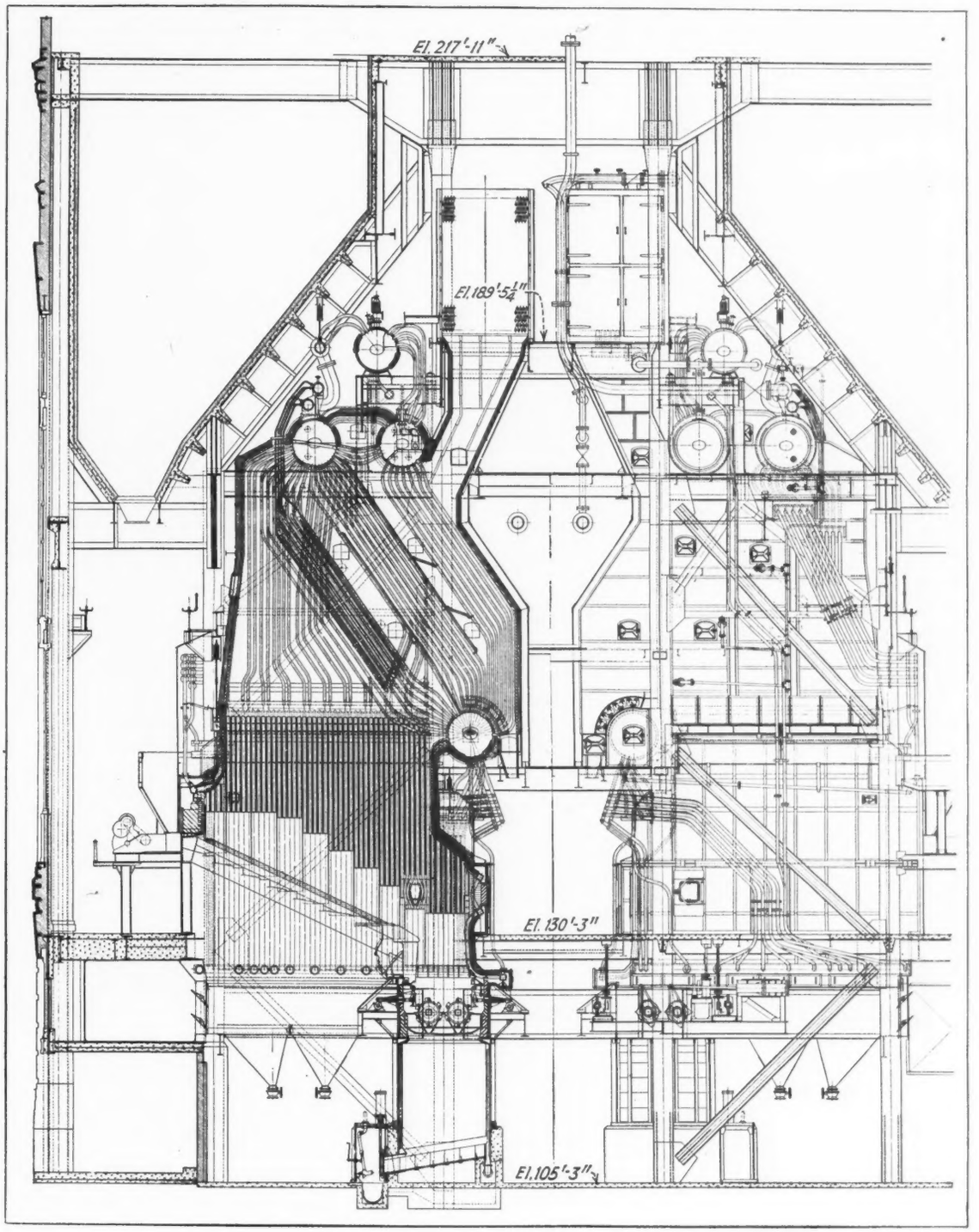
possible 24 valves per boiler, a saving of 112 valves on the eight boilers. Still another saving was effected by reducing the number of safety valves by using valves of larger capacity than had previously been the practice.

Another innovation in boiler accessory equipment for the Hudson Avenue extension was the elimination of water columns. The gage glasses are attached directly to the drum heads with the required crosses, gate valves and cocks. The gage glasses are of standard flat-glass construction, with three pairs of glasses staggered in one body to give a visible water level range of 30 inches.

Each of the three motor-driven centrifugal boiler-feed pumps for each bank of four boilers is designed to deliver 1,750 g.p.m. of feed water at 210 deg. F. to the boilers, against a total dynamic head of 1,450 ft. Under normal operating conditions only two are required.

Each pump is of the five-stage diffusion-vane type, with a horizontally split casing of high-test cast iron, and is bronze-fitted. The drive is a wound-rotor, 850-hp., 2,300-volt, 3-phase induction motor with a synchronous speed of 1,800 r.p.m. A secondary control equipment, designed to give seven points of speed adjustment, is used with each motor to obtain the desired flexibility in operation of the pumps.

Elevation and cross-section of the new bent-tube multi-drum Combustion Engineering boilers, four serving each 160,000-kw. turbine



POWER PHOTO

THESE STOKERS ON FOUR BOILERS FIRE THE COAL TO PRODUCE 160,000 KW. IN TURBINE GENERATOR NO. 8

WIDTH LIMITATION LEADS TO

WORLD'S LONGEST UNDERFEED STOKERS

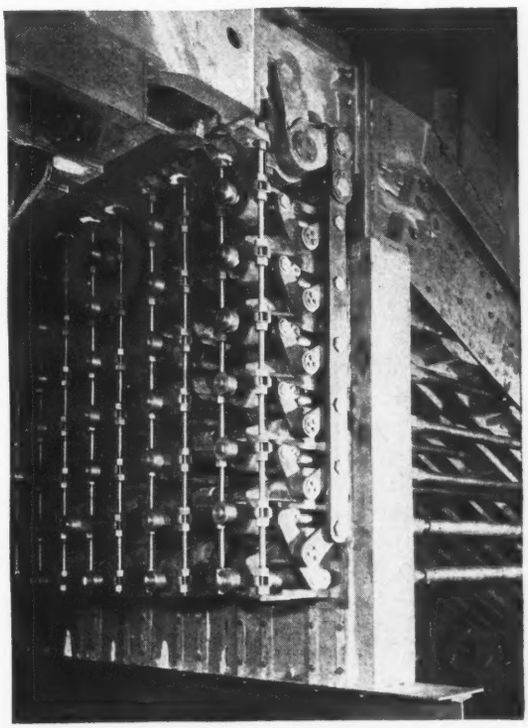
With the stokers, as with the boilers, space limitations were a primary factor in molding the design, resulting in the longest underfeed stokers yet built. This article also outlines the extensions to the coal- and ash-handling systems of Hudson Avenue

OTHER ARTICLES in this number of *Power* have referred repeatedly to space limitations as a primary factor governing design of equipment in the Hudson Avenue station. The four walls were fixed at the very start, as were also the building columns, locating the eight possible rows of four boilers each.

As the station equipment expanded within this pattern each additional turbine unit or group of units was made larger than its predecessor, yet each unit had to be served by four boilers (along with their economizers, air heaters, duct work and other auxiliary equipment) without interference with building columns placed when the station was laid out, and without neglecting the space requirements for proper operation and maintenance of the equipment.

The problem presented to the designers of the steam-generating equipment for Units No. 7 and 8 was to provide a certain steam output capacity to serve the two 160,000-kw. turbine units. A preliminary investigation showed that this might be accomplished in either of two ways: first, to duplicate essentially the previously installed equipment as regards size of boiler and stoker units within the boiler house and to make up the additional capacity needed by the construction of slightly larger capacity units in a new building to be installed on the station wharf; or, second, to increase the size of the eight boiler units to be provided within the station to obtain the required capacity from them.

The amount of heat required from the boiler units was determined after a review of the entire station capacity. It was assumed that 90 per cent of the station boiler capacity would be available for service at the time of peak station load and that this should be capable of maintaining full rated turbine output capacity under conditions of turbine back pressure corresponding to highest circulating water temperature. It was further decided that this 90 per cent of boiler capacity should be capable of maintaining this output for periods of five hours per night for six consecutive nights. The chief limiting factor in determining this capacity was found to be in the stokers. As the specification was finally released to the stoker manufacturers, a requirement of 4,160,000,000 B.t.u. per hour was set up, to be obtained from eight boilers and stokers. This corresponds to an output of approximately 460,000 lb. of steam per hour from each boiler and applies to the five-hour duration. This output compares with the 340,000 lb. per hour obtained from the preceding boiler and stoker design—an increase of about 35 per cent.



Individual pusher-rod adjustments are conveniently made in a space behind the boiler control panel

To obtain this output, stokers were proposed having a length of 26 ft. 8 in., from the front wall of the furnace to the rear apron of the ashpit. This length exceeds by three feet that of any previously built underfeed stoker. The width of these stokers is 26 ft., which provides

fifteen retorts. This width had been previously found to be the greatest that could be installed between the existing building columns and is possible only because of the use of the thin water-cooled type of furnace wall instead of a heavy refractory wall.

The stoker is of a design similar to that installed at Delray station, in Detroit, except that the length is greater. Its construction features include horizontal drive rods to each pusher, the strokes of which can be individually controlled. Another is the large ashpit storage space.

To accommodate a stoker of this length it was necessary to have the clinker-grinder roll shafts straddle the building column at the rear of the stoker. The unusual size of the rolls, which have a diameter of about 34 in. outside of teeth, permitted this to be done. This location of the stoker was decided upon as the most practicable, considering space requirements both in front of and in the rear of the stoker, together with the available position of the boiler and the requirements of furnace design.

After consideration of the depth required beneath the stoker, to provide ample ash-storage space for the periods between sluicing operations, and also to care for the headroom requirements for passage underneath the stoker windboxes, and to permit the installation of forced-draft fans and ducts, the elevation of the stoker was determined as shown. The relation of the stoker to the operating-floor level of the older portion of the boiler room is such that convenient access can be had to the secondary pusher stroke controls from the main operating level. The furnace observation doors at the rear of the furnace are also so located as to be accessible from this level.

Structurally the retorts of the underfeed stoker are uniformly loaded beams supported at the two ends. Provision for expansion in these stokers was made by supporting the steel members of the retort support by means of a hinge-pin construction at the front end and by supporting them on rollers at the lower end.

The new stokers are driven by an hydraulic variable-speed transmission. By lowering the installation cost this transmission offered a considerable saving over the variable-voltage, direct-current motor system previously used in this station and the flexibility of speed control obtained is the same in each case. Hydraulic drive is also applied to the clinker grinders. The oil pump for this equipment is located remotely from the hydraulic cylinder which drives the clinker grinder. Since this cylinder is in a very congested area the elimination of bulky mechanical transmission and speed-reducing devices was desirable.

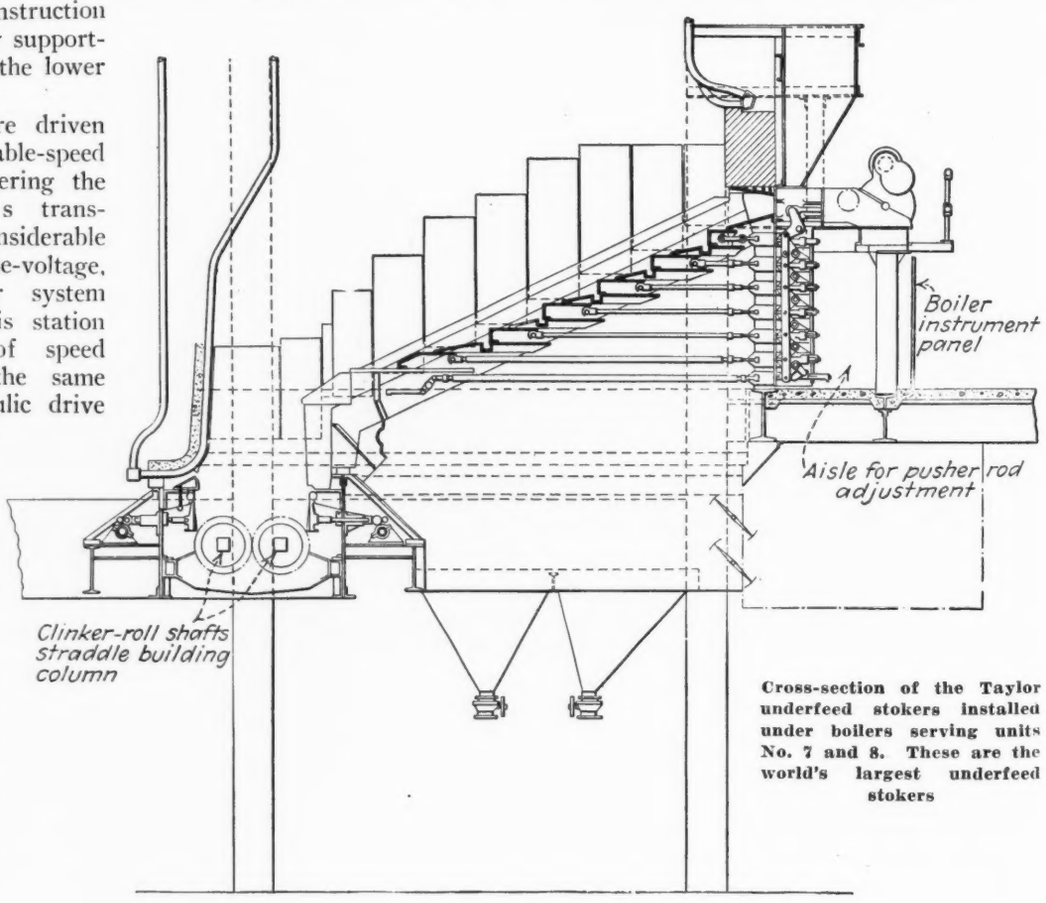
The table lists the guarantees made for these stoker units with coal having a heating value of 14,000 B.t.u. per hour.

Evaporation per Boiler, Lb. of Steam per Hour	Duration, Hours	Coal Feed Rate Lb. per Sq.Ft per Hour	B.t.u. Released Per Cu.Ft. of Furnace per Hour
530,000	2	82	57,000
487,000	5	73	50,700
452,000	Continuous	65	45,500

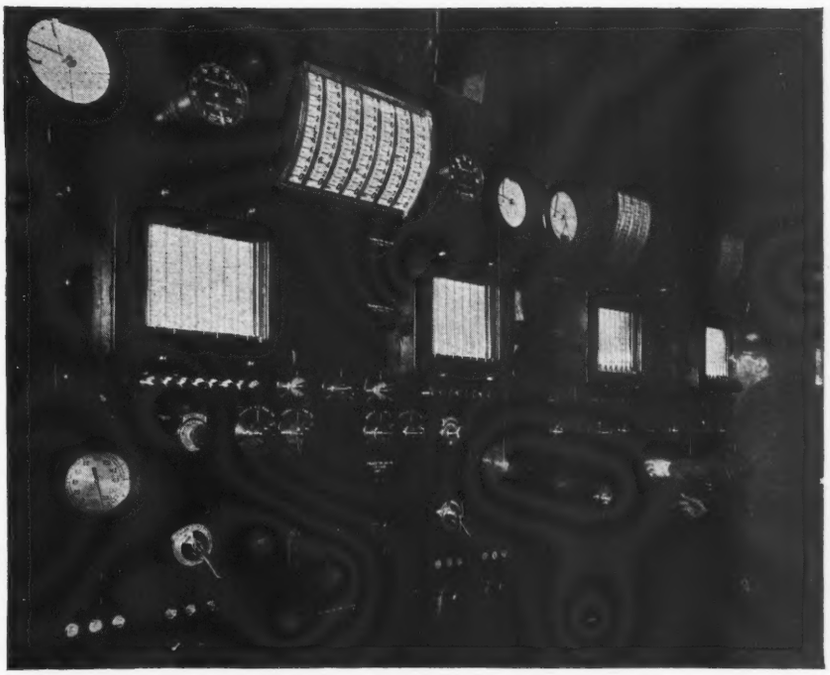
Coal and Ash Handling

Coal- and ash-handling facilities for the new steam-generating units are essentially an extension of the previously existing station facilities. Coal hoisted from steamer or barges at the river front by any of the three electric coal hoist towers is distributed to overhead bunkers by an electric coal road employing cars of five tons capacity. On its way to the bunker each car of coal is weighed. Coal is delivered from the bottom of the bunkers, through electrically operated gates, to traveling lorries, which distribute it to the various stoker coal hoppers in each aisle. The coal fed to each stoker is weighed, making it possible to keep accurate performance records of each day's operation of each boiler.

Ash hoppers below the stoker clinker-crusher rolls are of cast-iron, brick-lined construction, with a concrete base. The capacities of these hoppers, as compared with those provided for previous units, have been increased to provide for the greater coal consumption of the new boilers. Three oil-operated vertical gates are located at the base of each hopper. When these gates are opened, the ash can be sluiced out by means of horizontal high-pressure water jets—manually controlled. This ash then falls into a trench running the length of the station. Through this trench it is automatically transported by the high-velocity water system to a settling basin on the wharf. Ash is removed by clamshell bucket and loaded on scows.



Cross-section of the Taylor underfeed stokers installed under boilers serving units No. 7 and 8. These are the world's largest underfeed stokers



Central combustion control panels for the entire high-pressure section of Hudson Avenue. The panel at the left is for the new extension

AUTOMATIC COMBUSTION CONTROL

EXTENDED TO NEW SECTION

STEAM PRESSURE at Hudson Avenue is kept constant within practical limits by an automatic combustion-control system which varies the gas flow from and coal feed to the stokers. The control elements of this system are regulated through the medium of air pressure. Oil under pressure is used as the "motive power." In addition there is automatic control of furnace pressure.

In the low-pressure section of the station, on Units 1, 2 and 3, control of coal feed to the stokers, and of forced-draft pressure, is obtained by varying the speed of direct-current motors, which are on a Ward Leonard control system. The gas flow from the furnaces is varied by control of the outlet damper, there being no induced-draft fans.

On No. 4 unit coal feed is controlled in the same manner as on Units Nos. 1, 2 and 3. The air-duct pressure and suction at the induced-draft fans are controlled by speed variation of wound-rotor motors which drive the forced- and induced-draft fans. The gas flow from the stokers is controlled by regulation of the outlet dampers.

On Nos. 5 and 6 rows coal feed is controlled as on the previous units. Air-duct pressure, however, is controlled by varying the position of vanes at the inlets of single-speed motor-driven forced-draft fans, and gas flow in a similar manner on the induced-draft fans. The latter are driven by two-speed induction motors, speed changes being accomplished manually.

New-Section Regulation Tied with Old

Regulation of the new Nos. 7 and 8 unit boilers and stokers is tied integrally with the control of the Nos. 4, 5 and 6 units through the master control equipment, and the oil pumps and compressors which comprise the motive power for regulation.

This master control includes four "supermaster" regulators (two actuated by the steam pressure and two by hand) and a supermaster gage box. In addition, each individual row of high-pressure boilers (Units 4 to 8) has its own "section master." The steam-pressure-actuated supermasters translate changes of steam pressure into changes of air-loading pressure, which are distributed by means of an air tunnel to the various section masters. The manually operated supermasters permit hand adjustment of the air-loading pressure, which may be distributed through a second air tunnel to any or all of the section masters, as desired. Selection of manual or automatic regulation for any row of boilers is afforded by means of a throwover cock at each section master.

The air pressure, regulated by the supermasters and distributed through the air-loading tunnels, may be throttled through a rating control valve just ahead of each section master. This affords a means of proper division of load among the various rows of boilers. The section masters serve as distribution points for the various pieces of equipment to be controlled on any one row. Bleed-off needle valves are provided in each section master as a means of ratioing the air volume of the boilers to stoker speed and forced-draft duct pressure for the most efficient operation.

With the installation of the Nos. 7 and 8 units it was necessary only to extend the air-loading tunnels and install two new section masters. The arrangement of the masters, various instruments, and controls may be seen in the accompanying photograph of the high-pressure control board.

The Master Control Panel

This control board is used also as a centralized control station for hand regulation in the event that it is desired to control any or all units independently of the regulators. To this end transfer switches are provided for selecting hand or automatic regulation of the forced- and induced-draft fan vanes, and hand pilot valves for controlling the forced-draft duct pressure of any row of boilers.

The Nos. 7 and 8 unit equipment controlled by auto-

matic regulation consists of sixteen three-speed vane-controlled induced-draft fans, seven single-speed vane-controlled forced-draft fans, eight hydraulic-motor stoker-drive units and eight inlet dampers.

Elaborate provisions made for the automatic control of forced- and induced-draft fans are outlined in the succeeding article, dealing with the design and operation of the fans.

Hand Regulation of Draft Fans

For hand regulation of the induced-draft fans electrically operated transfer valves and pilot valves have been provided in conjunction with the induced-draft fan regulators. When it is desired to manipulate the vanes by hand, the control-room operator uses a transfer switch on the master panel to actuate the transfer valve and thus substitutes a solenoid-operated pilot valve for that operated by the regulator. By push buttons on the stoker panel a stoker operator can then manipulate the vanes through the solenoid pilot valve.

Hand regulation of the forced-draft fans is afforded by means of two oil pilot valves in the control room. These may be substituted for the regular control by turning the forced-draft transfer switch to the hand position.

An inlet damper, interposed between the forced-draft duct and the stoker windbox, is regulated to maintain a slight draft over the fire at all times. Each damper is controlled by a weight-loaded overfire-pressure regulator operating in conjunction with a relay cylinder and pilot valve. There is no connection between these regulators and the section master.

To insure regulation of the inlet dampers, and to provide oil pressure at all times for the hand-operated pilot valves, a separate oil line has been installed for this equipment. This is backed up by an emergency pump designed to start immediately if the normal oil-supply pumps should fail.

Control of Hydraulic Stoker Motors

The stokers provided for the Nos. 7 and 8 boilers are driven by hydraulic drive. This consists of a constant-speed alternating-current motor driving a pump unit, which in turn drives a hydraulic motor connected to the line shaft of the stokers. By adjusting the position of the eccentric of the pump of each stoker the speed of the stoker can be varied from idle to full speed. The eccentric is adjusted by a small pilot motor.

To control the speed of the stokers it is necessary only to actuate the pilot motor on the eccentric in such a manner as to balance the air-loading received from the master against a pressure created by the stoker-regulator speed element connected to the stoker line shaft.

The stoker regulator is of a new type, and is entirely electrical except for a dashpot which acts as a stabilizer. The design of the regulator is such that large changes in rating cause the pilot motor to run continuously and small changes cause it to run intermittently. Both the number of interruptions and length of pilot-motor running time between interruptions vary with the magnitude of the load changes.

In order that the speed to which the stoker is regulated may be changed from time to time for varying fire conditions a needle valve is provided on each boiler panel to permit local readjustment of the stoker air loading.

Push button operation is also available for control of stoker speed if the regulators are out of service for any reason.

▼ ▼ ▼

16,000 HP. TO DRIVE INDUCED-DRAFT FANS

IN MANY PLANTS it has been found that insufficient draft has been the factor which prevented design capacity from being reached. With this almost general experience in mind the forced- and induced-draft fans at Hudson Avenue have been designed with liberal capacity so that this relatively less-expensive equipment would not limit the capacity of the boilers and turbines.

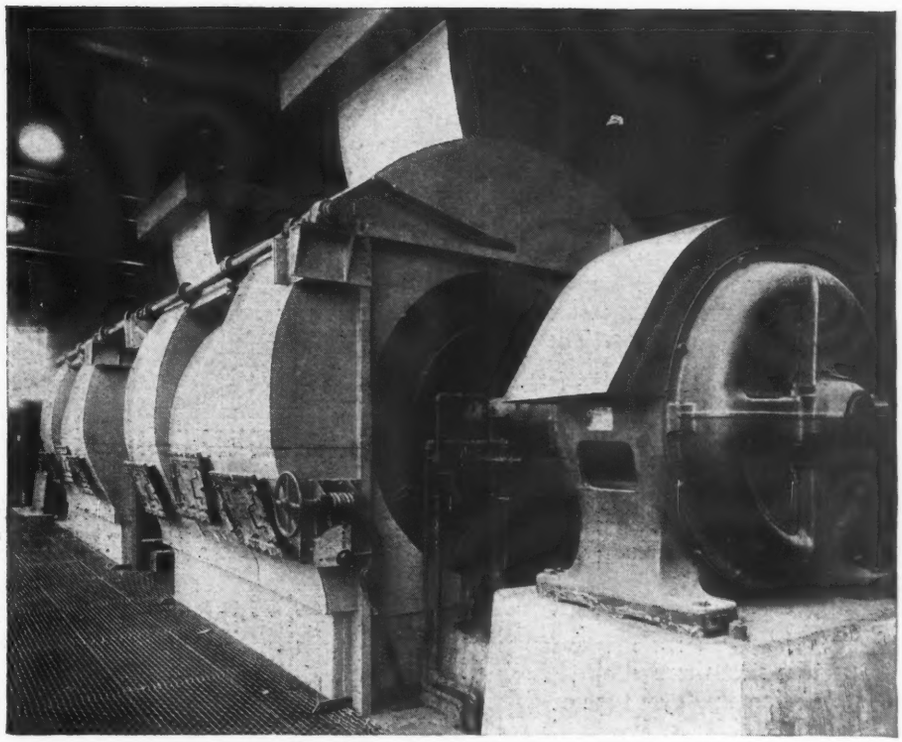
The volume capacities of the fans were based on the assumption of 30 per cent excess air and the combustion of 62,000 lb. of coal per hour in each boiler. For the induced-draft fans 15 per cent was added to take care of possible leakage. In order to simplify friction calculation, the entire leakage was assumed as occurring immediately above the economizer.

The pressure requirements were based upon a consideration of the manufacturer's requirements, the guaranteed pressure loss through equipment, the calculated loss in connecting ducts, and the stack effect. In the case of the forced-draft fans a liberal allowance was made for duct friction, as at the time the fans were purchased the actual arrangement of duct and fans had not been definitely determined.

The forced-draft fans for all previous units were in the boiler house basement, but the basement space available for the fans for No. 8 unit had to be left open for a driveway. Room for three forced-draft fans was found on the boiler room floor at the river end of the Nos. 7 and 8 rows of boilers. Four fans were placed in the basement approximately under No. 7 boilers. These fans and those in the boiler room discharge to a common duct, so that seven fans are available to supply air to eight boilers. Each of the forced-draft fans has a capacity of 200,000 c.f.m. against a 10-in. static head, which will permit full load on units Nos. 7 and 8 with six fans in operation. They are driven by single-speed induction motors of 500 hp. at 900 r.p.m. Volume control is obtained by inlet vanes which are operated by combustion control equipment.

The vane controls of the seven forced-draft fans are operated by a single regulator which balances the master air loading against the forced-draft duct pressure common to Nos. 7 and 8 boilers. This regulator is provided with two pilot valves which in turn control two master relay cylinders. One of these master cylinders is for the

four fans in the basement below the No. 7 row of boilers, and the other for the three fans on the boiler room floor. Each master relay cylinder operates the vanes of one fan and a jack-shaft which interconnects all fans of each row. These jack-shafts actuate the pilot valves of relay cylinders on each of the remaining fans and control the vanes in accordance with the master relay cylinder. By this arrangement the vane position is maintained identical for all fans.



Induced draft fans serving No. 7 row of boilers

At the discharge of each fan an unbalanced outlet damper is provided which closes automatically when a fan is shut down, thus preventing air in the duct from blowing out through the fan. To prevent a disturbance of forced-draft duct pressure when another fan is started, the unbalanced dampers are equipped with dashpots which make the dampers open gradually, thereby allowing the regulator to close down the vanes as the outlet damper of the started fan gradually opens.

In considering this scheme of group control for the forced-draft fans for units 7 and 8 it was felt that it might also be applied to the forced-draft fans of units 4, 5 and 6. Originally, a regulator had been provided on each forced-draft fan, but with the revised arrangement one regulator was provided for each row. A similar change was made to the induced-draft fans of No. 4 unit which substituted 4 regulators for the 8 previously used. By these changes sufficient regulators were salvaged from units already installed to equip the entire No. 7 and No. 3 boilers with regulators.

Two vane-controlled induced-draft fans each of 155,000 c.f.m. at 405 deg. and 20-in. static head are provided for each boiler. The fans are above the cinder catchers in a monitor on the boiler house roof. They were selected so that one fan will carry the boiler up to 420,000 lb. of steam per hour, maximum rating being 530,000 lb. per hour. Under this condition, however, the fan is not operating at its best efficiency, and therefore two fans are generally in operation.

The fan characteristics are such as to give a rising horsepower curve; therefore, the motor drives were selected so that with one fan running wide open they will not be overloaded. This resulted in the installation of three-speed 1,000-hp. induction motors for each fan, whereas the horsepower required at the fan design condition is 750 hp. The three speeds are obtained from two windings, 600 and 1,200 r.p.m. being had by re-connecting one winding and 900 r.p.m. with the other winding. With two fans operating 450,000 lb. of steam per hour can be secured at medium speed. At low speed the horsepower rating of the motor is sufficient to permit operation without overloading of one fan on cold air for the purpose of ventilating the boiler during maintenance work.

The fan cases and inlet scrolls are provided with removable liners to take wear due to cinders. To prevent cinders from cutting the two outer rivets at the joints between blades and the shroud and center plate cast-steel inserts are bolted at the blade tips.

Leaf dampers are provided above and below each fan so that it may be isolated for maintenance work. The outlet dampers close automatically when the fan is shut down, and dashpots prevent too-rapid opening.

Air volume through each boiler is controlled by one regulator provided for each pair of vane-controlled induced-draft fans. This regulator operates the vanes so as to balance the air loading received from a section master against the draft taken at the boiler outlet. This regulator is integrally connected by an oil pilot valve to an 8 x 7-in. relay cylinder which drives the interconnected vanes of the two fans.

To keep the induced-draft fan vanes in an operating range at all times it is necessary that the fan speed be changed or that a second fan be started or stopped. This operation is cared for by the stoker attendant, who either makes the operation remotely from the stoker panel or signals to the fan attendant to make the change. The stoker attendant is guided as to the time to make a speed change by stoker-control panel signal lights, which indicate the approximate vane position.

Considerable attention was paid to the matter of induced-draft fan speed change and the starting and stopping of fans, to insure that these operations would cause as little disturbance as possible to furnace draft and air flow. To assist regulation during a fan speed change a set of coils, energized by a fan-speed control switch and designed to exert a force on the regulator weigh beam, have been provided which cause the regulator to close or open the vanes rapidly for a brief interval as the fan speed is being accelerated and "decelerated" respectively. The dashpots on the outlet dampers also assist in the starting or stopping operation.

New Type of Cinder Catcher

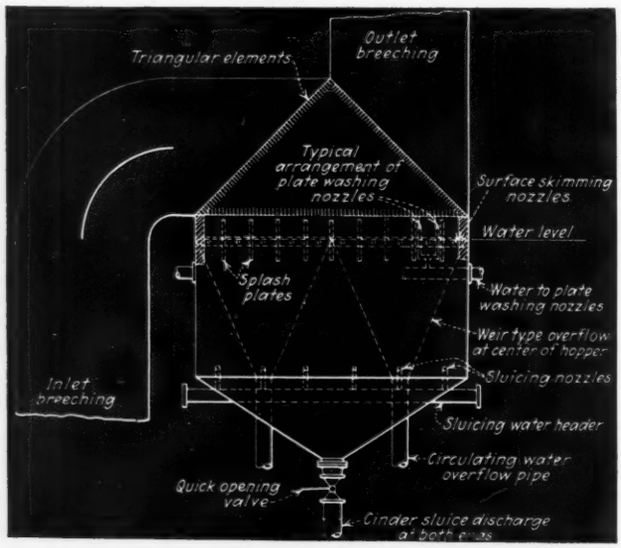
DEVELOPED FOR LAST UNITS

The basic features of the new design are wet collection of the cinder and separation by change of direction of the gas flow. Severe corrosion due to wet collection has been provided against

AVAILABLE SPACE was a primary factor in the choice of equipment installed at Hudson Avenue for removing cinders from the flue gas. Another was the desire to install the most efficient apparatus that would not necessitate major structural changes. The equipment installed recently with Nos. 7 and 8 units removes a high percentage of the dust and cinder from the gas, and will produce a dust condition in the neighborhood of the plant that is felt to be satisfactory.

The cinder catchers for all of the boiler units in the station are of simple construction, and employ inertia forces and change of gas direction as the basic method of separation. The first three rows of boilers in the station employ a type of cinder catcher in which the flue gas is made to make a turn of about 180 deg. around a baffle placed over a cast-iron tank containing water. The change of direction throws out the cinder particles, which are caught in the water.

Because of higher ratings and space limitations it was known that this type of cinder catcher would not perform satisfactorily for the subsequent units, all of which are of larger capacity. With Units Nos. 4 and 5 a different type of cinder trap was installed, which consists of a series of vertical curved plates or baffles arranged in staggered formation so that the cinders that separate out from the gas fall to the bottom of the trap and are removed dry. Trouble was experienced with the dry cinder removal, particularly in Unit 5, where because of station arrangement the cinder catcher was installed ahead of the economizer. The higher temperatures and greater gas volume encountered at this location account for the increased difficulty of removing the dry cinder and the resulting lower efficiency.



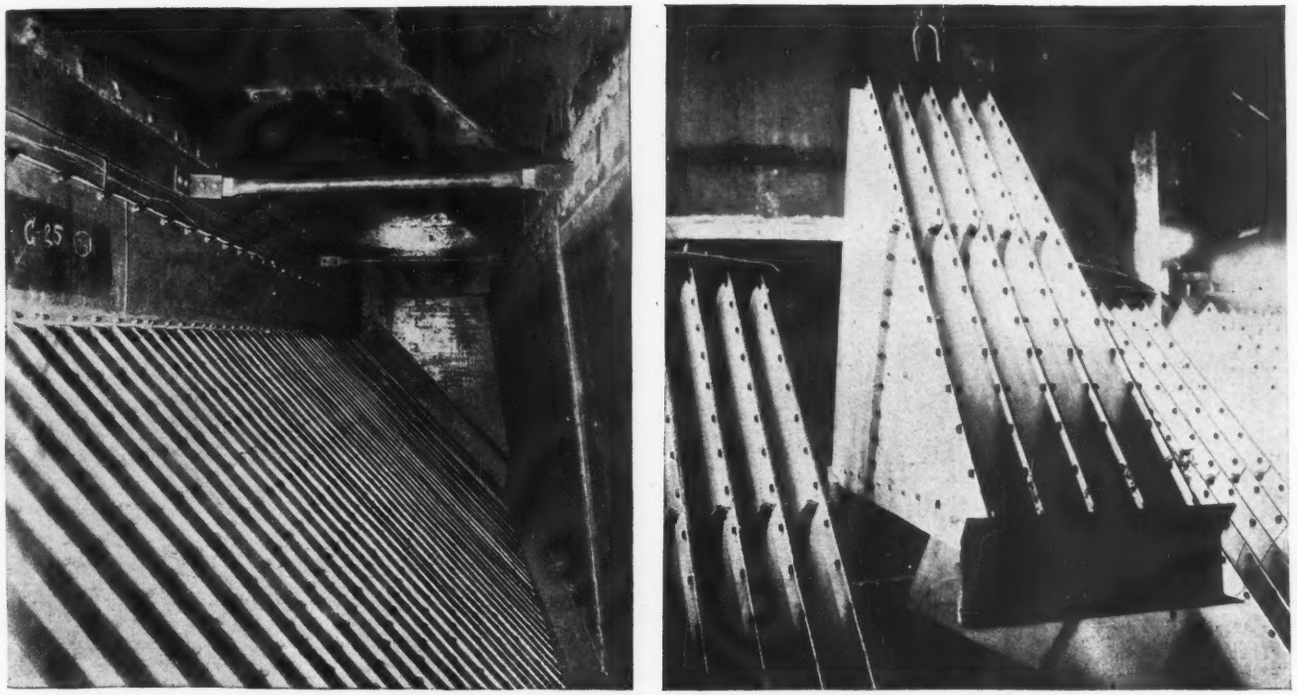
Cross-section of cinder catcher showing arrangement of nozzles for cleaning plates skimming, water surface and sluicing cinders

For Unit 6 a new design of cinder catcher was evolved and experimented with on one boiler. This work led to the design used for Units 7 and 8 and is also being installed in the remainder of the No. 6 row of boilers.

The basic principle of the new cinder catcher is much the same as that employed in the first three units in that it depends upon the reversal of the gas stream over a water surface. However, the flue gas is broken up into a large number of narrow streams, making it possible to bring the water surface in intimate contact with a much greater proportion of the gas, so removing a larger percentage of the cinder. The particular arrangement employed also made possible reasonable gas velocities within the space limitations existing.

The cinder catcher consists of 120 isosceles triangular plates 12 ft. long on the bottom edge and 6 ft. high. The plates are supported parallel to each other in a vetrical position over a trough of water 12 ft. wide and 26 ft. long. On the inlet side alternate plates are bolted together so that sixty openings $1\frac{1}{4}$ in. wide are formed between the plates. On the outlet side the opposite alternate edges are joined forming sixty outlet openings $3\frac{3}{4}$ in. wide. The gas flows in and down between the plate envelopes to the bottom edge of the triangular plate and into the space above the water tank. The water level is maintained seven inches below the bottom edges of the plates. The gas turns through 180 deg. and flows up and out through the $3\frac{3}{4}$-in. spaces between the adjoining plates.

The abrupt change of direction of the narrow stream of gas throws out a large portion of the dust. Also, the water surface is so close to the bottom edge of the triangular plates that the dust particles have to travel but a short distance to the water surface, where they are caught and removed from the gas. This arrange-



The triangular plates were assembled in sections before placing in the cinder catcher. A white enamel is used on the plates to facilitate inspection

ment has proved more efficient than the cinder catchers of the first three units, largely because on these the distance between the water surface and the baffle plate was about three feet and which could not be reduced without creating too high gas velocity. This three-foot distance provides an opportunity for the gas stream to carry with it some of the finer cinders before being caught by the water.

In the Nos. 7 and 8 catchers nine splash plates are placed lengthwise and at right angles to the triangular plates. These extend down into the water for several inches and are intended to prevent undue splashing. These splash plates are occasionally washed clean by nozzles that direct the water spray along their surface. There are two nozzle headers, each serving to wash half the length of the splash plates.

At each end of the water trough, which is 4 ft. deep, surface-skimming nozzles are provided between each pair of splash plates and located just below the surface of the water. The circulation set up by the nozzles keeps the water surface free of cinders that tend to float, carrying them to the center of the water trough, where they flow over a discharge weir which extends across the width of the catcher.

For cleaning out the cinder that sinks to the bottom of the trough two sets of nozzles are provided at the center on both sides of the overflow weir. These sluice the cinders to the ends of the trough, where they are discharged and piped to the ash-removal system in the boiler house basement. The cinder is sluiced out about once a shift, depending upon the boiler rating. The normal flow of salt water to the cinder catcher is about 100 g.p.m., but during cleaning periods about 400 to 600 g.p.m. is used.

One of the interesting developments in connection with the triangular element plates is the use of porcelain enamel, similar to that used on electric refrigerators, to protect the metal from the severe corrosive action of the fine spray mixed with the sulphur from the flue gas. The acid condition thus set up results in complete deterioration of a plain steel element plate in a short time. The only material thus far found satisfactory to resist the combined action of the corrosive and erosive action of the cinders and salt water and the relatively high temperature (400 deg. F.) is porcelain enamel.

The present design of plate elements is such as to make it easily enameled and erected without injury to the corrosion-resisting surface. A removable section has been incorporated at the point of greatest wear which is expected to result in relatively low maintenance charges. Considerable effort has been directed toward obtaining an enamel surface as nearly free from pin holes, which are starting points for corrosion, as is commercially possible. To show up the small pin holes required microscopic investigation, an inspection standard unusual in the enameling industry.

Many materials were tried for splash plates, including several high chromium alloys, silicon iron, non-metallic substances such as micarta, transite, asphalt coatings and cast-iron splash plates, which last about six months.

Asbestos ebony, which was adopted for the splash plates in Units 7 and 8 lasts a year or more.

The spray nozzles are of brass and last about six months. Experiments are now being carried on to determine whether the spray nozzles can be made of lava, which has been found practically impervious to the corrosive action. The water trough is of cast iron, lined with paving brick for a distance of 16 in. down from the top of the tank. The remainder of the tank is lined with a waterproof asphaltic material.

POWER PHOTO

ONE OF THE WORLD'S TWO LARGEST TANDEM-COMPOUND TURBINES, 160,000 KILOWATTS

Two Tandem Units Add 320,000 Kw. to Station Capacity

The two new turbines at Hudson Avenue are the largest tandem units in operation and are coupled to the largest generators yet built. These units generate 40 kw. per sq.ft. of turbine room floor area and are installed in space originally planned for a 50,000 kw. unit.

▼

IN DECIDING the size of the last two units at Hudson Avenue, the generating stations, the distribution systems and the load of the Brooklyn, New York and Queens systems were treated as a unit. Considered in this way the system was of such size as to justify the installation of the largest turbine units that could be placed in the space available and still maintain operating space consistent with reliability. These two units are the last to be installed at Hudson Avenue and were limited in length by the width of the turbine room which is 94 ft. 6 in. and in width by the distance between centerlines of 42 ft. In addition consideration had to be given to the space available for condensing equipment and to arrangements for removing the generator rotor.

The turbines selected to satisfy these conditions, and which are now in operation, have each a nominal rated capacity of 160,000 kw. They are coupled to single-winding generators rated at 200,000 kva. and 80 per cent power factor. The unit has an overall length of 85 ft. 8⅜ in., a width of 24 ft. and is 24 ft. above the floor line The turbine is tandem-compound de signed to operate at 1,800 r.p.m., with steam conditions at the throttle of 400 lb. gage pressure at 730 deg. temperature. The curves of Fig. 1 show that the heat rate obtained from acceptance tests under these steam conditions and at 1:0 in. Hg. vacuum is less than the guarantee at all loads. At a 29-in. Hg. vacuum the turbine is capable of an output of 170,500 kw.

Steam is brought to each unit in a 24-in. line which branches just before the throttle valves to two 22-in.-diameter lines. These are located under the turbine room floor, but the throttle valve stands are above the floor. After the two throttle valves, which embody the usual emergency release cylinders, the two lines loop under the front end of the turbine and then rise vertically on the opposite side to a steam chest mounted on top of the high-pressure cylinder. The size of throttle valve required if a single valve were used, and the necessity of obtaining sufficient flexibility in these loops, were the factors that dictated the dual line construction. Before entering the steam chest the steam passes through a pair of strainers, each of which is made up of two monel wire meshes, one coarse and one fine, which are wrapped around a frame of steel.

The steam chest contains eight valves, which admit the steam at five points in the turbine. The first admission point has two valves, the second and third admission points one valve each. These four valves all admit steam to the first stage of the turbine, but to separate sections of the nozzle circumference. The fourth admission point is in the nature of an overload connection and contains two valves admitting steam to the second stage. The fifth, or second overload point, has two valves admitting steam to the fourth stage. All valves have an auxiliary valve embodied in them which opens first and admits steam under the main valve disk, balancing the pressure and thus reducing the force necessary to open the main valve. The camshaft which operates the admission valves is geared through a rack and pinion to an oil-operated piston which in turn is controlled by a pilot valve actuated by the usual form of flyball type governor. A hand-operated overload control valve has been installed in the oil supply to the operating piston, which prevents the overload valves from opening while the turbine is being started. This is done to force all of the steam through the first stage and so eliminate uneven heating which would occur if all valves were opened when the unit is started. It also requires less steam for starting.

The high-pressure cylinder contains fifteen pressure stages, the first stage being velocity compounded with two rows of moving buckets. The low-pressure cylinder has four double-flow stages. Throughout the units the blades are of Ascoloy No. 33 and are fastened to the wheels by external dovetails. The blading of the last stage has an effective length of 38 in. and is the largest blade yet manufactured. The tip diameter of the last wheel is 12 ft. 9½ in., which at 1,800 r.p.m. gives a tip velocity of 1,205 ft. a second.

The low-pressure buckets and nozzles are of the twisted type to take care of the different velocities at the root and tip of the bucket. To reduce to a minimum the steam leaking around the tip of the blades, metal packing strips are fastened to the cylinder casings opposite each

row of blades except the last two low-pressure rows.

Steam is extracted for feed-water heating from two openings in the high-pressure cylinder. One 18-in.-diameter opening is provided for bleeding steam at the eleventh stage, and two 24-in.-diameter openings are provided for taking steam from the fifteenth or last stage in the high-pressure cylinder.

Special provision has been made for the removal of moisture formed in the fourteenth, fifteenth, sixteenth, seventeenth and eighteenth stages, and in the crossover between the low- and high-pressure cylinders. This is particularly important in this unit because of the high tip speed of the low-pressure blades. In the top and bottom casings at each of these stages a relatively narrow channel has been provided through which moisture thrown out by centrifugal force will pass into a larger collecting passage as shown in Fig. 2. In each of the lines draining these moisture-removal channels an orifice is installed having an aperture large enough to permit the passage of the amount of water that collects, but at the same time limiting the steam leak-off to a minimum. The moisture collected from the sixteenth, seventeenth and eighteenth stages is discharged to the condenser, while the moisture collected from the fourteenth and fifteenth stages and crossover is discharged to the low-pressure feed-water heater.

Temporary arrangements were made so that a separate measurement of the moisture collected from each of these stages could be made during the acceptance test. Each stage moisture drain line was provided with a temporary tee connection installed above the orifice, so that this stage could be drained by gravity at stage pressure to a temporary volumetric test tank, located at a lower elevation, other moisture drain lines simultaneously discharging normally through their respective orifices to the low-pressure heater or condenser shell. This arrangement has permitted, it is believed for the first time, the measurement of the quantity of moisture which can be separated from the steam in each stage under actual operating conditions. The table gives the results of these tests.

There are two crossover pipes from the high- to the low-pressure cylinders, each pipe being 5 ft. 9 in. in diameter. The arrangements for taking care of cylinder expansions are such that no expansion joint was required in each crossover connection. Around the circumference of the last stage an angle iron has been installed to prevent moisture thrown off by the last wheel from impinging against the top condenser tubes and causing erosion.

MOISTURE EXTRACTION

	100,000 kw. Load		170,000 kw. Load	
Stage Drains	Moisture Extracted, Lb. per Hr.	Per Cent of Moisture Present Extracted in Drains	Moisture Extracted, Lb. per Hr.	Per Cent of Moisture Present Extracted in Drains
14, 15, Cross over Bowl	16,000	33.0	16,500	22.1
16, 17, 18	5,350	8.3	5,250	5.5
Total.....	21,350		21,750	

The unit has six main bearings, giving two bearings each for the high-pressure and low-pressure turbine shafts and generator shaft. The high- and low-pressure turbine shafts are connected by a semi-flexible single-jaw coupling that has no floating element and permits axial movement only, while the low-pressure and generator shafts are connected by a solid coupling. The flexible coupling made necessary two thrust bearings. The high-pressure end thrust is of the ball seat type, but that at the front end of the low-pressure cylinder is of the ring type.

Oil for lubricating and governing is provided by two shaft-driven pumps operating in parallel. Each pump has two sets of gears, one providing oil at 125-lb. pressure for governing and the other lubricating oil at 30-lb. pressure. Two steam-driven oil pumps are provided for starting and emergency service, one of these being a

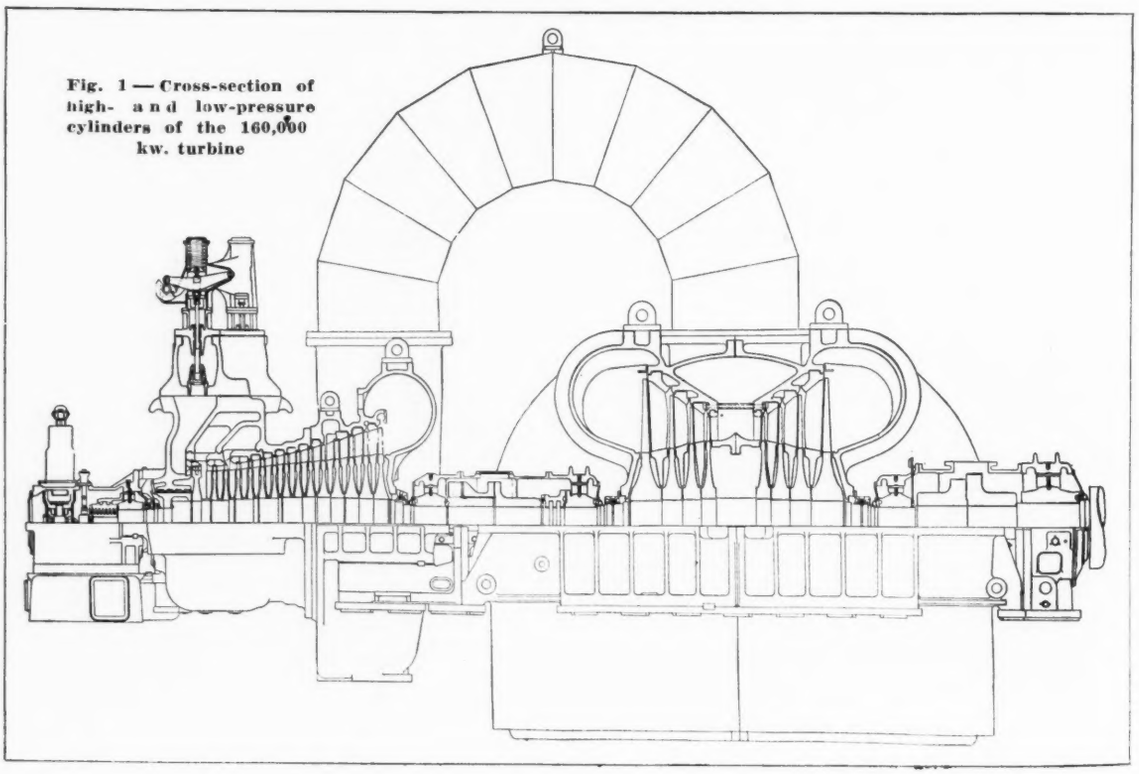


Fig. 1 — Cross-section of high- and low-pressure cylinders of the 160,000 kw. turbine

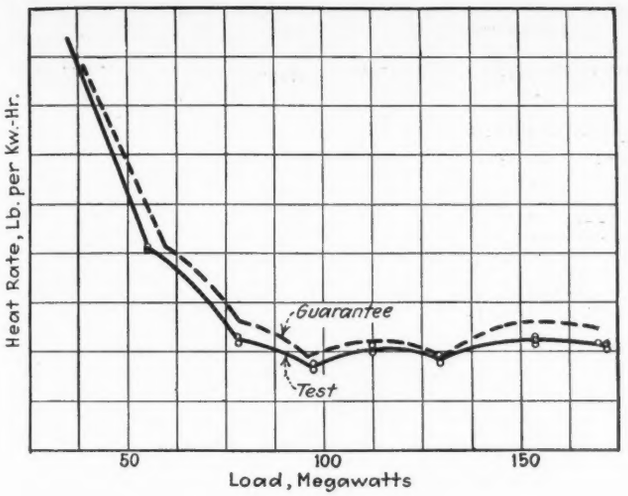
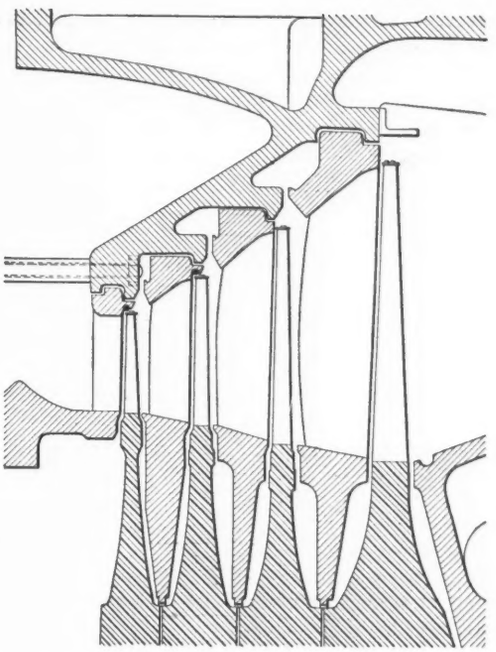
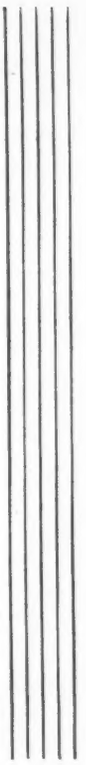


Fig. 2—Curves show comparison of heat rate guaranteed and that obtained on test

Fig. 3—Enlarged section of low-pressure stages, showing channels for removing moisture





spare. To conserve space and to make it possible to conceal major runs of oil piping the oil tank was incorporated in the foundation steel supporting the No. 1 main bearing. This unique feature was accomplished by designing the cross supports under the high-pressure end of the machine as box girders, which are 92 in. wide, 82 in. deep and 21 ft. long. All connections are riveted and the joints between cover plates, web plates, and end diaphragms are seal-welded. The capacity of this tank is 5,300 gal., and in addition 1,200 gal. of oil is in the piping to the cooling system and about 300 gal. is in the circulation system to the bearings making 6,800 gal. total in the oiling system.

All turbine shaft glands have combination labyrinth and water seals. The high-pressure end has also a steam seal, which is used only during the starting period. The water seal at the high-pressure end is of the circulating type requiring a continuous supply of water for cooling, while the other three glands are of the gravity type.

A turning device has been provided for shaft positioning during maintenance work and for turning the turbine rotor slowly during shutdown periods. The unit is of the spur-gear type, capable of turning the shaft at the unusually low speed of $1\frac{1}{4}$ r.p.m. Bearing lubrication while the shaft is turning at this low speed is provided by auxiliary oil pumps.

The turbine-generator is supported on structural steel foundations, the distance between the base of the machine and the column bases being approximately 40 ft. The main girders employed to frame in these columns are 7 ft. 5 in. deep. The condensers are bolted directly to the turbine exhaust flanges and are partly supported by springs resting on concrete piers.

The steel structures were designed to support the machine loads plus 25 per cent impact, condenser loads, floor loads, and dead loads. The maximum calculated deflections are 0.045 in. for the longitudinal generators supporting girders, 0.030 in. for all other girders, and 0.030 in. for the axial deflections of columns. Longitudinal and cross bracing was designed for a horizontal force of 25 per cent of the machine load applied at the centerline of the machine. Space limitations necessitated placing some of the cross bracing between the two machines, so that the foundations are rigidly tied together.

The low-pressure cylinder is anchored in an axial direction by a key near its transverse centerline. The high-pressure cylinder is keyed to the low-pressure cylinder so that expansion of the turbine is toward the front end. The front end bearing pedestal is mounted so that it will slide on the pedestal base.

Arrangements for ventilating and cooling the generators depart from customary practice in that four motor-driven fans of 57,500 c.f.m. capacity each are mounted on top of the generator. The fan housings form an integral part of the duct work, the motors being located externally so as to be readily accessible. These fans draw air out of the generator and discharge it down through air coolers located on both sides of the machine above the floor line. From the coolers the air passes down through ducts under the floor and then through openings in the generator stator. Both fin-tube air coolers have four sections through which salt water is used. This arrangement of fans and coolers simplified the arrangement of air ducts and was in this case particularly satisfactory because of station space limitations. Normally four fans are in operation at full load, but in emergency three fans will cool the generator.

The salt water from the air coolers is discharged to the condenser circulating water discharge tunnel, which is approximately 45 ft. below the coolers. This difference in elevation would produce a high vacuum in the air cooler which in turn would release occluded gases from the salt water. To prevent the corrosion that these gases would cause orifices are placed in the discharge lines so as to decrease the vacuum created in the cooler and prevent the release of the gases.

A development made in connection with the last unit is the installation of a set of supervisory control instruments for determining the vibration of the turbine-generator at four points, the expansion and eccentricity of the high-pressure turbine shaft, and unusual sounds in both the high- and low-pressure turbine cylinders. Detecting pick-up devices on the machine itself are connected to indicating and recording instruments on a remotely installed panelboard. A speed indicator has also been placed upon this panelboard to assist in the

interpretation of the readings on these instruments during the starting-up period. These remote instruments are being installed for the purpose of obtaining information as to their practicability for future station development.

The over-all length of the unit is only 8 ft. $9\frac{5}{8}$ in. shorter than the width of the turbine room. Special attention, therefore, had to be given to means of installing and removing the generator rotor. By reinforcing the steel-work to sustain the weight of the generator rotors it was possible to make use of the two bridges whose primary purpose was to carry electrical cables from the power house to the switch house across the street. These bridges came at the centerline of each machine, so that it was only necessary to construct a carriage and tracks that would carry one end of the rotor out onto the covered bridge. In this position the rotor can then be easily rolled into the stator. The tracks are placed in a pit about $2\frac{1}{2}$ ft. below the floor line. The construction of the pit and carriage is such that the upper portion of the carriage can be removed and stored in the pit alongside the lower portion below the floor line so that floor plates conceal both track and carriage.

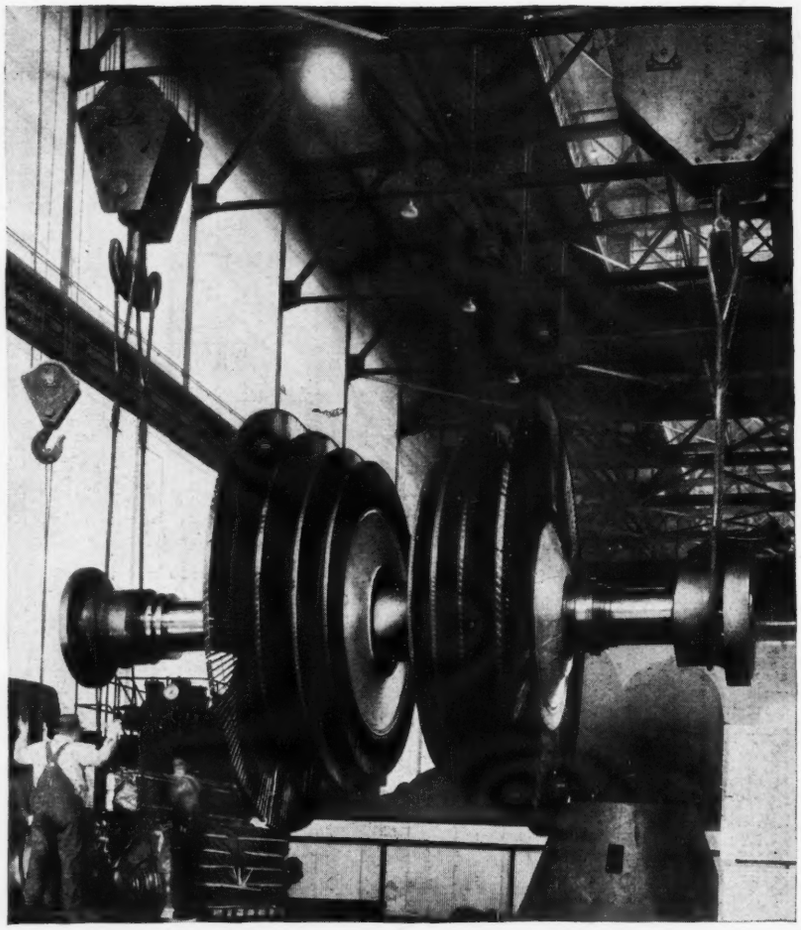


Fig. 4—Lowering the low-pressure spindle into the cylinder

Unlike the double-winding 160,000-kva. generator at the Fourteenth Street station of the New York Edison Company, the Hudson Avenue units have but one winding, which was made possible by the station bus arrangement. Current generated at 16,500 volts is stepped up in a 16,500-to-27,600-volt double-winding auto-transformer. The output windings of the transformer connect to separate sections of the bus through oil switches of 1,500,000 kva. interrupting capacity. Switches of the same capacity also tie each winding separately to the synchronizing bus through reactors. The double winding in the transformer divides the generator output so that the short-circuit currents are limited to values that can be handled by breakers of capacity now available. By dividing the generator output in the transformer instead of the generator only one auto-transformer per phase is required for each generator instead of two.

The heaviest piece handled during construction was the stator, which with winding in place weighs 528,000 lb., requiring the use of both 150-ton turbine room cranes. The generator rotor for this stator is 41 ft. $11\frac{1}{4}$ in. long, 5 ft. $2\frac{3}{8}$ in. in diameter and weighs 270,000 lb. The high-pressure turbine shaft is 19 ft. long and 2 ft. $4\frac{1}{2}$ in. in diameter at its largest section.

Although secondary in its importance to economy in operation and ruggedness and reliability in construction, the question of the appearance of the completed units was given particular attention throughout the entire course of design. With the ready cooperation of the manufacturer, and by the aid of a scale model, several designs for the steel lagging, access stairways and piping were given consideration. To achieve a layout which would be in keeping with the rest of the machine and with the existing station, the steel lagging over the high-pressure cylinder was laid out along simple yet massive lines, all small piping was concealed beneath it and all joints were covered with batten strips. The oil supply and return headers were run entirely beneath the floor and all branch line piping where exposed was kept within the contour of the machine. Attention given to such minute details as square-cornered insulation for all flange and manhole covers, vertical railing stanchions, and the covering of all dirt collecting pockets with steel plates added to the trimness of the whole unit. Access stairways and platforms were likewise kept within the boundry lines of the machine, not only unifying the appearance as a whole, but also increasing the available walkway space around it.

The acceptance test on No. 7 turbine-generator unit, results of which are shown in Fig. 1, was made entirely on the regenerative cycle, which is the normal method of operation. The turbine and condenser were completely isolated from other units in the plant by means of double valves with leakoffs between. The main condensate, that is, the portion of the throttle flow that passed entirely through the turbine, was weighed in the station weigh tanks. The combined condensate from the two extraction heaters, which accounted for the remainder of the throttle flow, was measured volumetrically in closed station tanks. With this arrangement no loss occurred due to evaporation of the hot heater condensate. Both the weigh tanks and the volumetric tanks discharged into a common receiving tank from which the water was pumped through the two extraction

Fig. 5—Wheel for 19th stage assembled for factory inspection

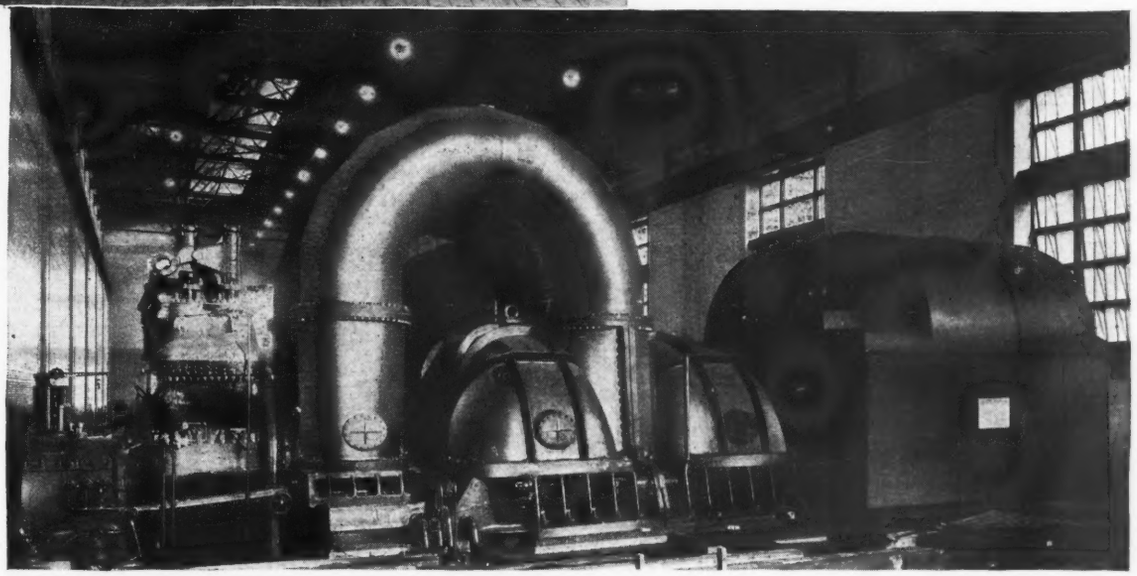


Fig. 6—No. 7 unit during erection showing steam chest before insulating

ture, a mercury thermometer was used. For pressure measurements Bourdon test gages and mercury U-tubes were employed, depending on the magnitude of the pressure measured. Special consideration was given to obtaining an accurate measurement of the average exhaust pressure. Eight connections were used, four near the outer shell and four in the central portion of the exhaust section. Attached to the end of each line was a wire-mesh basket-type tip. When calibrated these showed little variation from the true static pressure regardless of the direction of the steam flow. An absolute-pressure gage[1] was used on each line, and an arithmetical average of the readings of the eight gages was taken as the true exhaust pressure.

Measurement of the generator output was made at the six high-tension (27,000-volt) terminals of the auto-transformers with an entirely independent metering installation. Six side opening, interleaved, through-type current transformers were used. The six potential transformers were connected in parallel with the station transformers (connected line to neutral). High-grade voltmeters, ammeters and single-phase wattmeters were used, and readings were taken every minute. The net output of the unit was taken as being the sum of the high-tension output of the auto-transformers, exciter output, and the losses of the auto-transformers and low-tension leads, minus the inputs to the generator field and generator fan motors. The auto-transformers were operated without load on the tertiary winding.

heaters. The surge tank for the unit is connected between the two heaters and had to be left in the circuit during the tests. The regular make-up line was shut off, but variation in the level of the receiving tank and surge tank affected the rate of flow through the heaters and was considered, therefore, as make-up, either plus or minus. The correction to the heat rate, however, for make-up for this source was small, generally 0.1 per cent or less.

Throttle, heater and condensate temperatures were read with calibrated thermocouples and temperature indicator. As a rough check on the throttle steam tempera-

[1]For description of these gages see July 5, 1927, issue of *Power*.

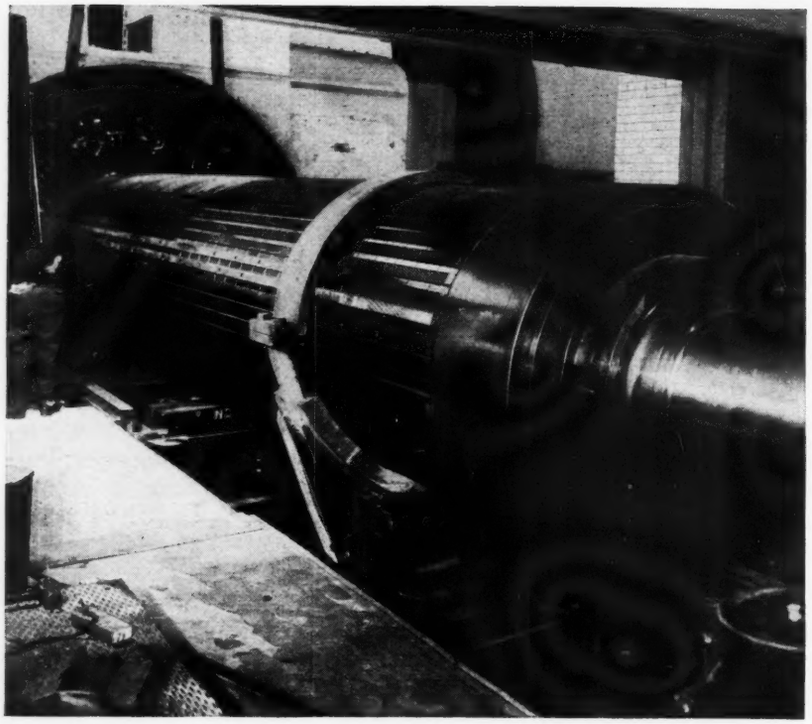


Fig. 1—In this position the rotor is ready to be moved into the stator

GENERATOR ROTOR HANDLING —A DESIGN PROBLEM

Space limitations required special handling facilities to permit placing the generator rotor within the stator. The rotor is 41 ft. 11¼ in. long, 5 ft. 2⅜ in. in diameter and weighs 135 tons

AS the width of the turbine room is only 8 ft. 9⅝ in. greater than the overall length of the unit, special attention had to be given to a method for installing and removing the generator rotors. A bridge the primary purpose of which is to carry the electric cables from the power house to the switch house is located on the centerline of each machine and joins the turbine room with the switch house across the street. The existing steelwork of each bridge was reinforced, and a section of it adjacent to the power house was elevated to permit the installation of a track runway capable of sustaining the weight of one end of the generator rotor. The manufacturers designed a pair of carriages and a suitable pulling tackle so that it was possible to move the rotor onto one end of the bridge, from which position it could be rolled into the stator.

It was possible to install the carriage tracks in a pit 2½ ft. below the turbine floor level to permit this. The construction of the outboard carriage is such that the upper portion can be dismantled and stored within the pit, together with the lower portion and other parts of the pulling tackle. Removable floor plates are installed over the track pit, concealing both the track and carriages.

Apparatus furnished by the manufacturer included outboard and inboard generator rotor carriages, an electric winch, and the necessary tackles and rigging. This equipment was used in conjunction with the 150-ton turbine room crane and the carriage runway. Fig. 3 illustrates the intermediate steps in the installation procedure. The 135-ton rotor was carried by the turbine room crane into position *A*, which marks the limit of approach of the crane hook to the turbine wall. In this position the outboard end of the rotor has entered the bridge, so that this end may be supported in the outboard carriage.

This carriage is shown in Fig. 4 and is mounted on a ball bearing swivel which carries a yoke that may be rotated and clamped about the body of the rotor in position *A*. A temporary blocking installed under the other end of the rotor permits taking a new hitch with the crane hook. With one end carried by the crane, and the other supported by the outboard carriage, the tackle rigging is used to move the rotor to position *B*. From this point it is swung to position *C* in line with the stator.

The second carriage is now mounted on the inboard end of the rotor. This device, illustrated in Fig. 1, consists of a pair of rollers that carry the clamp, which is attached to the inboard shaft journal, heavy copper shims being used to protect the bearing surfaces. This end of the rotor is supported by the carriage as it traverses the length of the stator, the carriage riding on a curved shim of ½-in. boiler plate placed in the air gap to protect the stator winding and to give an even surface for the carriage to roll upon. The pulling tackle is next reversed in direction, and with the inboard end supported by the crane, the rotor is drawn outward from position *C* until the inboard carriage rests on the air gap shim. Supported by the two carriages, the rotor is then rolled

forward until the extremity of the travel of the outboard carriage is reached at position *D*. This end is then picked up with the 150-ton crane and the movement progresses until the other carriage arrives at the extremity of its travel on the shim. The coupling end of the shaft is then beyond the stator. As the crane is equipped with an auxiliary 75 ton hook, the coupling end is slung from this. A new hitch is taken on the outboard end of the rotor with the 150-ton hook, permitting the rotor to be carried by the crane into its final position *E*.

To make the rotor carriages readily demountable, easy to store, and to secure maximum strength with the least weight, a welded construction of steel plate and structural members are employed. The outboard carriage yoke is arranged to swing upon a 4-in. diameter pin and to rotate on a race of 3-in. steel balls. All parts requiring lubrication or protection against corrosion during periods of non-use are equipped with lubricating fittings. To insure further protection during the expected long periods of storage, a dust guard is installed around the aperature between the upper and lower ball races.

The electric winch is also of unusual construction. It will be noted that two independent tackle eyes are provided on either side of the outboard carriage from each of which a separate block and tackle is carried to the winch. To equalize the pull on these two lines of tackle, the winch drum was constructed in two halves connected with a differential gear, the differential gear housing being driven by electric motor through a worm and wheel. The tackle consists of two 1½-in. lines of manila rope and two pairs of triple-sheave steel tackle blocks, the whole system being designed to exert a static pull of 25 tons.

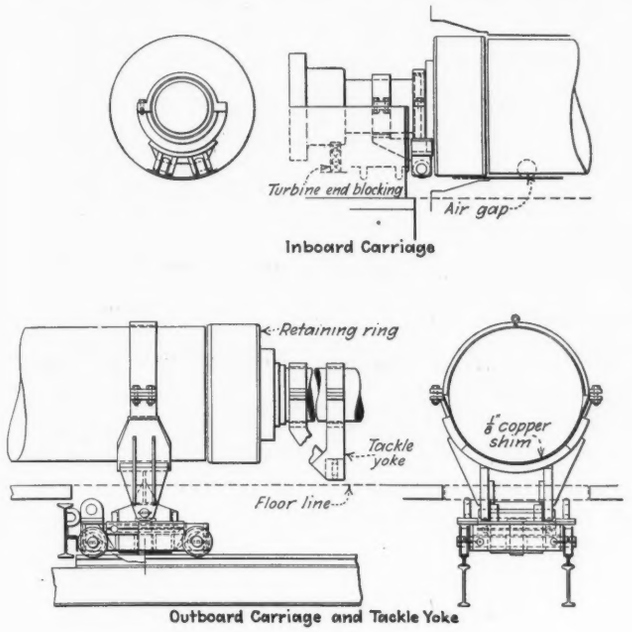


Fig. 1—Above is shown the design of the inboard carriage and below the outboard carriage

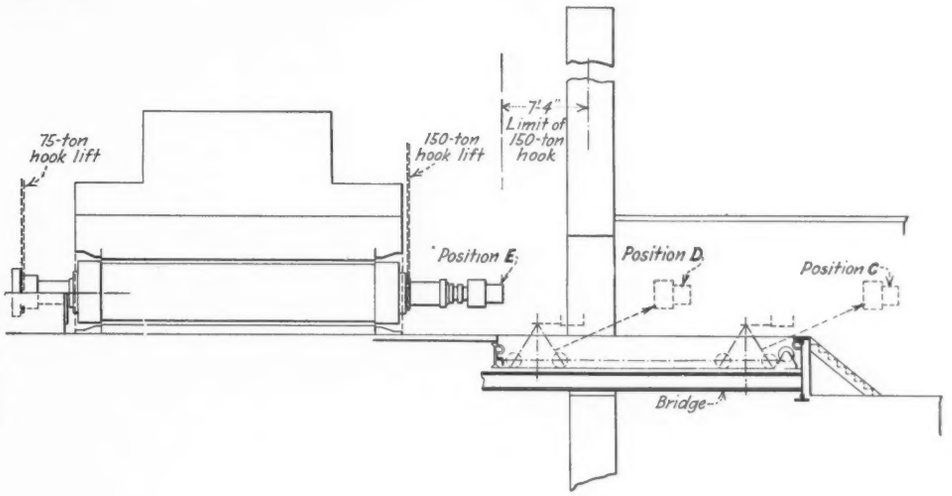


Fig. 2—Elevation through center line of bridge and generator showing how one end of bridge was raised to accommodate track for the outboard carriage

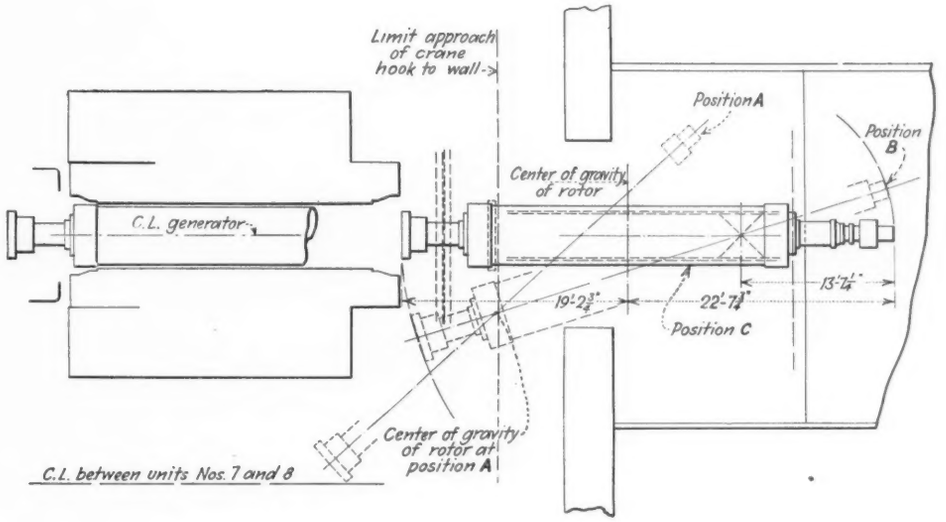


Fig. 3—Plan showing various positions assumed by the rotor during the handling process

POWER PHOTO

101,000 SQ. FT. OF CONDENSING SURFACE IN A SINGLE SHELL HANDLES THE EXHAUST OF EACH 160,000-KW. TURBINE

WORLD'S LARGEST CONDENSERS

• • • 0.63 SQ. FT. PER KILOWATT

Each of the single-pass condensers serving the 160,000-kw. turbines contain the same tube surface, 101,000 sq.ft. They are materially different in arrangements for steam distribution and water circulation

IN SPECIFYING the condensers to serve the two 160,000-kw. units, which complete the Hudson Avenue station, no attempt was made by Brooklyn Edison engineers to dictate the features of their design. Each manufacturer was permitted to decide for himself the amount and arrangement of the condensing surface, the number of passes to be employed, and the arrangements made for air removal. Certain limiting space conditions were, however, given in order that the condensers would fit in with the general station design. In addition to these limiting conditions the manufacturers' engineers were given such information as the amount and temperature of the circulating water available, the expected steam flow and heat-consumption rate of the turbine at a one-inch back pressure, the effect of changes in vacuum on heat-rate consumption, and such additional factors as would permit the evaluation of condenser performance and its comparison with first cost. The method by which the condenser performance would be evaluated was given in the specifications, and it was the intent that each manufacturer should offer a condenser that would most economically meet the conditions of the service required, both operating and fixed charges on the first cost of the equipment being considered.

Probably the most important limitations which the manufacturers had to face was that of space. The condensers had to be designed so that they would fit between the turbine foundation columns which, for No. 7 unit are 24 ft. 8 in. apart, and for No. 8 unit 26 ft. 8 in. apart. The height between the turbine flange and the condenser room floor was also restricted to 34 ft. This limitation was imposed because it was impossible to raise the turbine room floor more than 5 ft. without making architectural changes that would detract from the building appearance. The length of the condenser was limited at one end because of the station feed-water piping, and tube removal space for feed-water heaters. At the other end limitations were set up because of the necessary location of circulating-water pumps and piping. In view of the extreme space limitations, it was decided that clearances of 2½ in. between the condenser and steel work would be considered a minimum. This entailed very accurate drafting work.

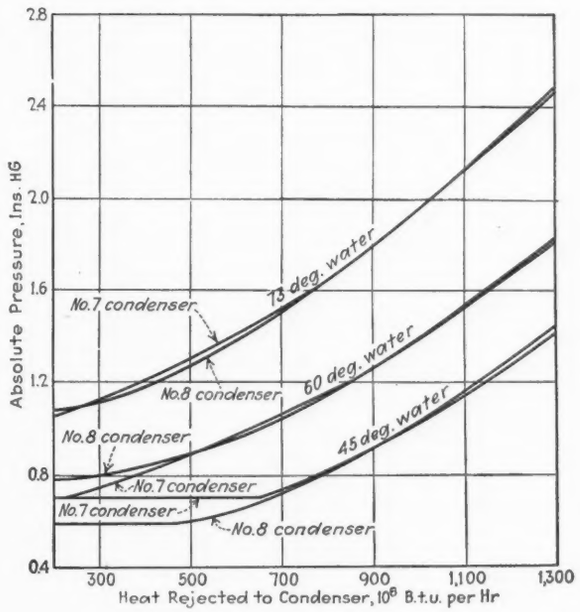


Fig. 1—Absolute pressures guaranteed with 70 per cent clean condenser

There are no valves in the circulating-water system, of 7 and 8 units. In all previous units in the station valves had been inserted so that either of the two circulating pumps could supply both halves of the condenser. The ability to supply both sides of the condensers from each pump was considered secondary to the monetary saving and improved hydraulic circuit made possible by their elimination.

Due to the fact that the inlet and discharge circulating-water canals had been installed for the entire plant when the first section was built, and that they were designed on the assumption that 50,000-kw. units would be installed throughout the station, it was necessary, in order

to maintain reasonable velocities, to limit the amount of circulating water available to each condenser to 200,000 g.p.m. This, it will be seen, provides 1.25 g.p.m. per kilowatt of installed turbine capacity.

Each of the condensers installed to serve the two units was obtained from a different manufacturer. Both are of the single-pass type, contain the same size and length of tubes, and the same amount of cooling surface, namely, 101,000 sq.ft. In other respects, however, they differ widely, both in theory of steam distribution and in outward appearance. The guarantees given for these two condensers at different turbine loads and for various circulating-water conditions are given by the curves in Fig 1. At the design load the vacuum guarantees of both condensers were identical.

The guarantees are made on the basis of a 70 per cent clean condenser. The cleanliness of the condenser will be determined by comparing the heat transfer of the new tubes with the heat transfer of groups of tubes in the condenser under the actual conditions existing in the condenser. The method of testing is explained in the article "Test Facilities at Hudson Avenue," on page 829.

Features of No. 7 Condenser

The condenser installed to serve No. 7 unit has a cylindrical shell, and the waterboxes are divided vertically so that each of the two 73,250-g.p.m. circulating-water pumps serve one-half of the condenser. The condenser has an over-all length of 41 ft., a height of 33 ft. 4½ in., and a width of 22 ft. 5 in. It contains 14,710 ⅞-in. outside diameter admiralty metal tubes having an active length between tube sheets of 30 feet.

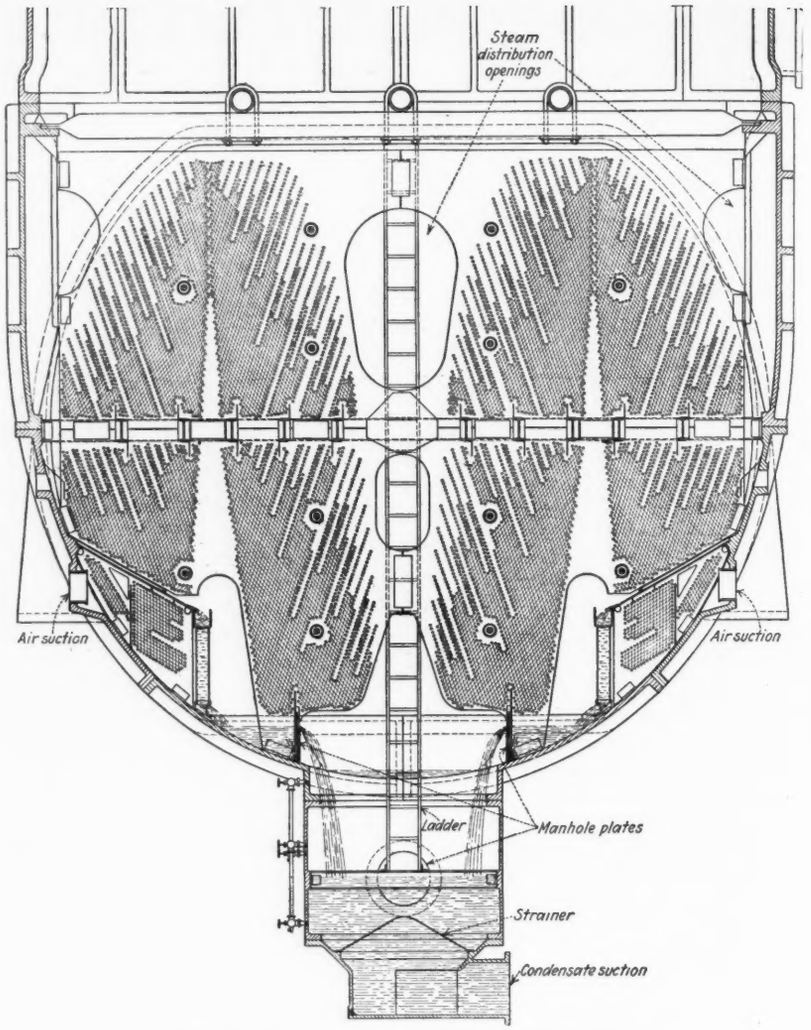


Fig. 3—Cross-section of single-pass condenser serving No. 7 turbine

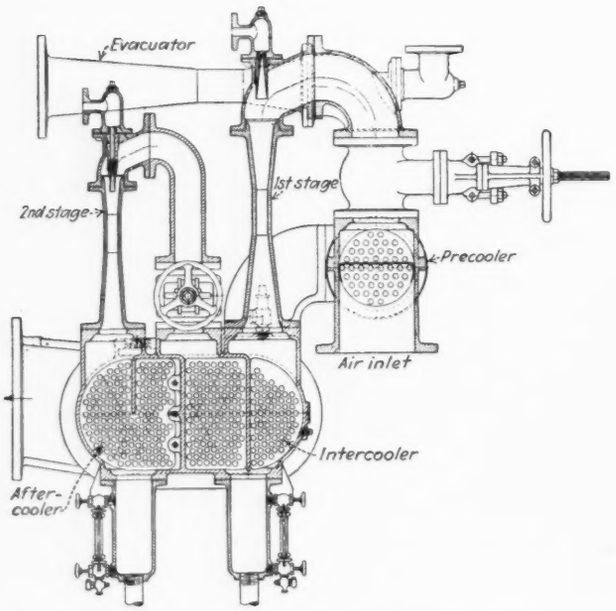


Fig. 2—Cross-section of steam-jet air ejector serving No. 7 condenser

One of the difficult problems that had to be solved in connection with the installation of this condenser, as well as No. 8 condenser, was the provision for adequate atmospheric relief. This was solved by installing two 42-in.-diameter nozzles on the neck of each condenser, together with two atmospheric relief valves. To get these atmospheric relief openings in the condenser it was necessary to change from a circular section at the valves to an elliptical shape at the condenser, to avoid interference with a 7 ft. 5 in. deep beam that supports the turbine bedplate. Other items that have to do with the outside features of the condenser are two 58- by 54-in. elliptical circulating-water inlet nozzles and two circulating discharge nozzles of the same size. The hotwell is cast in one section and bolted to the bottom of the condenser. It has a capacity of 800 gal. and is equipped with a bronze strainer and baffles to prevent a vortex being set up at the entrance to the condensate piping.

The condenser is bolted directly to the 20-ft. 10-in. by 20-ft. turbine exhaust opening, and part of the condenser load is supported on springs. The maximum allowable

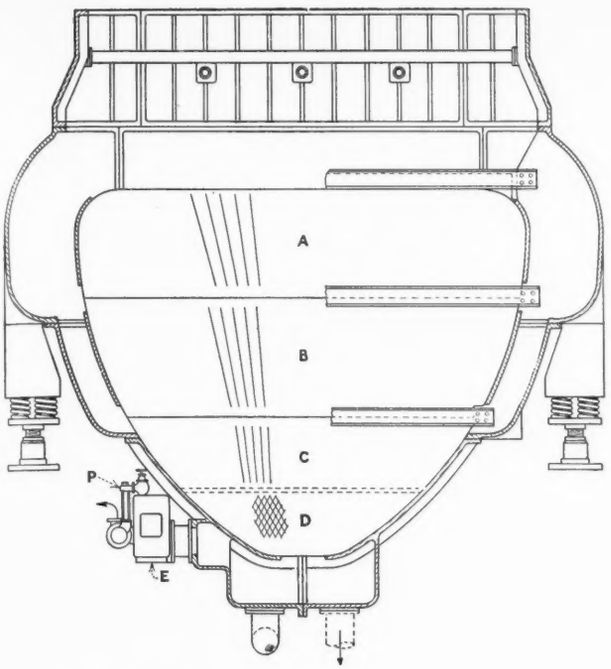


Fig. 4—Cross-section of single-pass condenser serving No. 8 turbine

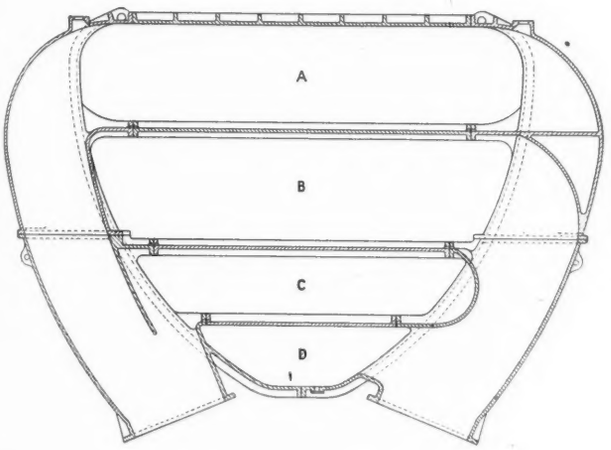


Fig. 5—The waterboxes of No. 8 condenser are divided into horizontal sections. Sections A and C are served by one pump and sections B and D by the other pump

operating load on the turbine exhaust is 500,000 pounds.

Fig. 2, a cross-section through the condenser, shows the arrangement of tubes and their relation to the condenser shell and hotwell. This arrangement of tubing is based upon the theory that the ideal condenser for short steam travel and minimum pressure drop would be a long thin rectangular bank of tubes laid out horizontally with the steam passing down uniformly through the bank in a vertical direction. Such a condenser is impractical because of space restrictions. A practical approach to this ideal is secured by folding the relatively thin tube layer back on itself in the form of an inverted U, the inner portion of which forms an exit lane leading to an air cooler section near the bottom of the shell. In No. 7 condenser two such banks are provided, one on either side of the vertical centerline, and form a wide venturi-shaped central lane extending from the top to the bottom of the condenser. This lane serves the double purpose of feeding steam to the tube banks on either side and of bringing steam at exhaust temperature into contact with the condensate at the bottom of the shell before it flows to the hotwell. The steam lane has been made of venturi shape in order that some of the velocity energy may be converted to pressure and thus increase the condensate temperature. Two additional steam lanes of gradually decreasing area are provided between the shell and the outside tubes, and extend down to the baffles which protect the air cooler sections.

There are two air cooler sections, one on each side near the bottom of the shell. These sections are of gradually decreasing cross-section, with a vertical baffle forming the apex so that the air is removed at relatively high velocity and is spread throughout the full length of the cooler tubes. The baffles which separate the cooler sections from the remainder of the tube banks are formed of double plates with a dead air space between to minimize transfer of heat from the steam side of the air cooler.

Condensate is drained from the air cooler baffles through brass pipes spaced at intervals along the length of the condenser. This prevents a continuous sheet of condensate from flowing in front of the air-removal section, which would chill the condensate and heat the air passing through the stream. One 10-in. air offtake

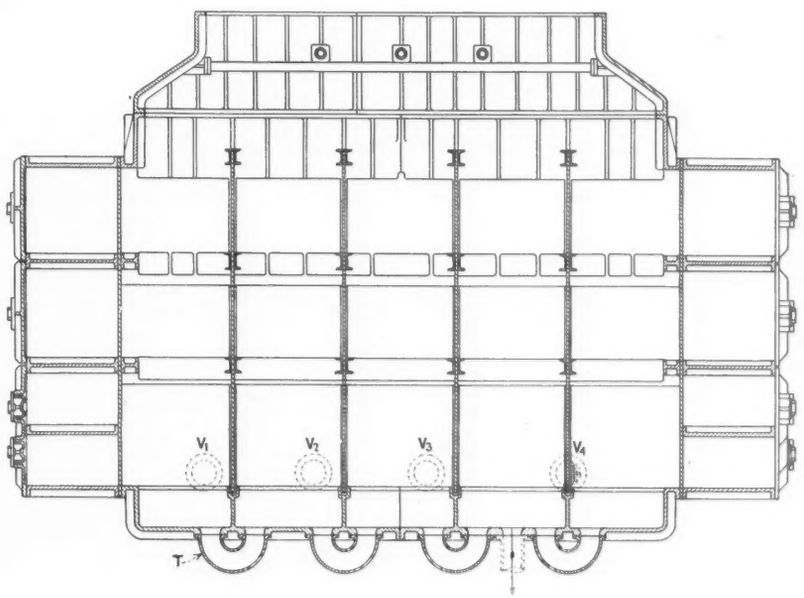


Fig. 6—No. 8 condenser is divided longitudinally on the steam side into five compartments. Each compartment is served by primary steam-jet air ejectors with a duplicate set for emergency. Air removal openings are shown at V, to V,

has been provided on each side of the condenser about midway between the center of the condenser and the cold end.

Baffles placed in the bottom part of the condenser are arranged to form a water seal, the full length of the shell, and prevents the steam immediately over the surface of the condensate from short-circuiting to the air cooler section. The arrows in Fig. 2 show how the condensate flows over the weir in a thin sheet to the central steam passage.

Tubes are supported by six intermediate muntz metal support plates $\frac{3}{4}$ in. thick. They are bowed upward at the center to provide drainage and resistance to vibration.

Provision for longitudinal distribution of steam in the condenser has been made on the theory that the steam should be allowed to flow freely to all parts of the condenser. Thus the tube support sheets have been provided with openings wherever possible in the entrance and exit lanes to permit longitudinal flow.

The tube sheets are of muntz metal 21 ft. in diameter and $1\frac{7}{16}$ in. thick. They are cut off top and bottom to 17 ft. 3 in. and were made in quarters, which necessitated the longitudinal and transverse braces of structural steel shown in the cross-section. The longitudinal members are fitted with steel angles top and bottom to prevent short circuit of steam from entrance to exit lanes. Tubes are held in both tube sheets by ferrules and fiber packing secured with screwed ferrules.

A manhole at the hotwell permits entrance to the central steam passage and removable plates in the weir give access to the exit lane. A ladder is permanently installed in the central lane, permitting passage up into exhaust connection. This open construction permits inspection of the tubes, tube support plates and other internal portions of the condenser.

Special attention was given to the design of the waterboxes in order to secure smooth flow and prevent liberation of dissolved gases that cause corrosion.

The air-removal equipment for this condenser consists of a three-element, two-stage steam-jet air ejector mounted on a surface-type inter- and after-cooler and having a total capacity to handle 33 cu.ft. of free air per minute saturated at 1 in. Hg. abs. and 71.6 deg. With all previous units rotating hydraulic air pumps were installed for emergency and starting up duty, but with No. 7 unit none was installed, and instead connection was made to this type of pump on No. 6 condenser. It is planned to use this connection only in case of emergency. For starting up purposes two hogging jets of large capacity are provided which exhaust to the atmospheric exhaust line instead of to the inter- or after-condenser.

The cross-section of the air ejector, Fig. 3, shows a small cooler in the air line ahead of the first-stage jet. This was considered desirable because of an unusually long air-removal line between the condenser and the ejector, through which it was believed sufficient heat would be absorbed to detract from the efficient operation of the air ejector.

Normally all of the condensate flows through the inter- and after-condensers to the generator air coolers. For use during the starting periods a bypass has been provided so that a maximum of 500 g.p.m. of condensate can be returned to the main condenser and so recirculated, thus insuring sufficient water to condense the steam supplied to the main jets. This arrangement was also carried out for No. 8 unit.

No. 8 condenser design is heart-shaped, with subdivision on the steam side into four horizontal banks extending across the condenser and into five compartments along the length of the condenser; on the water side it is subdivided by the waterboxes into four horizontal superimposed compartments. In the main shell are 14,550 admiralty metal tubes $\frac{7}{8}$ in. O. D. and having an active length of 30 ft. Its over-all length is 42 ft. 9 in. and its height 30 ft. $1\frac{1}{4}$ in.

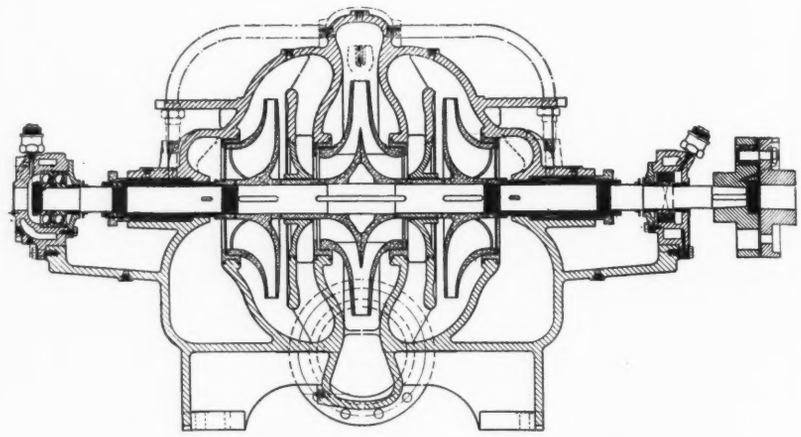


Fig. 7—Condensate pump for No. 7 unit. The shaft packing is supplied with sealing water from the first stage

Considering first the steam and air flow in the cross-sectional view, Fig. 4, the design is roughly analogous to the reverse of a steam turbine with two bleed points. Starting at the top, a bank of tubes *A* extends across the width of the condenser, with the tubes arranged in rows as indicated. Large areas are provided for the great volume of steam, the tube spacing in this respect being again analogous to the last rows of blades in a turbine. The areas contract as the steam flows through the bank. Banks *B* and *C* are similar in design to bank *A*, with further contraction in the areas and in the shell width due to the heart shape. Bank *D*, at the bottom, has the smallest width, terminating in a nose of relatively small area. The tubes in this bottom bank are on diagonal spacing.

Part of the steam, exhausted from the turbine instead of entering the tube bank directly, flows down the sides in bypasses to the second and third banks. This relieves congestion in the top of the condenser.

A rectangular hotwell at the bottom of the condenser collects the condensate and the vapor and air flow

through five openings to the external air coolers E. These coolers are built integrally and contain 1,000 sq.ft. of surface served with circulating water. The vapors make a number of passes over the tube surface. Primary steam jets P then extract the air at high vacuum and discharge to an intermediate vacuum of around 26 in. Hg. The compressed vapors and air are in turn discharged to an intercondenser and secondary steam jets, which compress to atmosphere in the usual way.

The temperature of the condensate corresponds to the average vacuum at the bottom of the condenser and is colder in winter than in summer. The condensate is reheated with steam from the exhaust of the turbine in an external-surface-type heater. A short section of the bypass on one side of the condenser is partitioned off to supply steam to the heater.

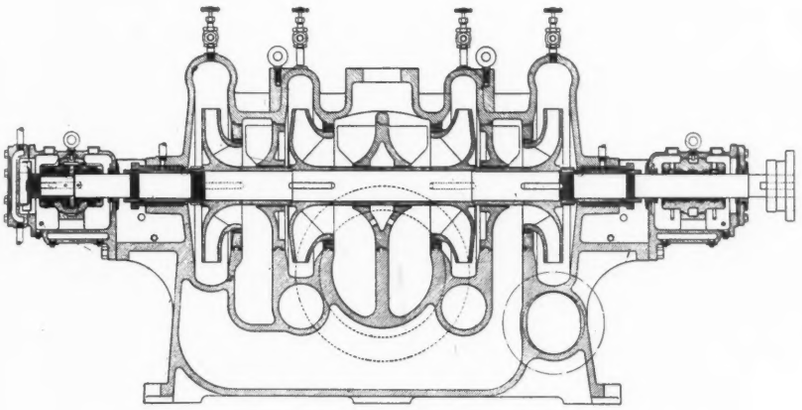


Fig. 8—Condensate pumps for No. 8 unit have two first stage impellers and one impeller of each of the remaining two stages

The condenser is divided longitudinally, as shown in Fig. 6, into five compartments by the four muntz metal tube support sheets which are made tight in the shell. The hotwell at the bottom has correspondingly tight partitions. Under the designed conditions, with 73-deg. water, 70 per cent clean tubes, and full load, the average water temperature in the first compartment is about 75 deg. and the average water temperature in the last compartment 88 deg. The condensation in the first compartment is, therefore, greater than in the last, amounting to approximately 320,000 lb. per hour as compared to 185,000 lb. per hour. The pressure differentials are maintained in the ratio of the squares of the loads. This is accomplished by independent vapor outlets V which connect to individual coolers and primary steam jets. Each jet automatically maintains the necessary vacuum at the bottom of each section. The fourth and fifth compartments are combined and served by one cooler and one set of steam jets. In this case, the difference in pressure required is obtained by an orifice installed in one half the vapor outlet V_4 which servies the two compartments.

Condensate flows from one compartment of the hotwell to the other through the sealing traps T and is finally removed from the hotwell through the condensate outlet shown. Hotwell depth is provided to accommodate the levels of water needed to balance the differences in pressure and cause condensate to flow through the traps. The water levels stand progressively higher toward the cold end.

Circulating Water Destribution

The design of the waterboxes is shown in Fig. 5. One pump supplies circuits A and C, the other pump to circuits B and D. The boxes consist of superimposed sections. Each box, in effect, is a square channel forming a continuation of the inlet water pipe. Space limitations required building the inlet pipes as part of the boxes. The guide vanes and flow paths incorporated in the design were based upon model tests.

Water circuit B is 5 ft. lower in elevation than the top circuit A. As previously mentioned, the turbine floor was raised 5 ft. and the condensers necessarily placed at high elevation above tide water, the highest tubes being about 36 ft. above extreme low water. With the design shown, the upper circuit could lose its water and the condenser still operate with the lower circuit at the 5-ft. lower syphon. This water circuit arrangement also gives added operating flexibility. The right-hand pump serving banks B and D can be run at reduced speed while the other pump is operated at full speed. Under intermediate load and water temperature conditions this results in a power saving. All passages in the boxes are arranged as smoothly as possible to prevent eddies and sharp turns.

Two 3,000-g.p.m. condensate pumps are installed for each condenser. They are driven by two-speed, pole-changing, 2,300-volt alternate current motors of 225 hp. The pumps for No. 7 unit are two-stage and have three impellers. The arrangement is shown in Fig. 7. No. 8 condensate pumps, Fig. 8, are three-stage and have four impellers. The first stage consists of two impellers with opposed inlets. The impellers for the last two stages also have opposed inlets and are at opposite ends of the pump, so that stuffing boxes are under pressure instead of vacuum to prevent inleakage of air. The condensate pumps for No. 7 are designed for 180 ft. dynamic head and the No. 8 pumps for 190 ft. dynamic head.

Each condenser is served by two single-stage, double-suction circulating-water pumps driven by two-speed, pole-changing, 2,300-volt alternate-current motors of 600 hp. No. 7 pumps, at high speed, supply 73,250 g.p.m. at a total dynamic head of 24 ft. Their capacity at low speed is approximately 48,500 g.p.m. One of the No. 8 pumps is designed for a dynamic head of 24.5 ft. and the other for 25.5 ft. Each supplies 72,750 g.p.m. at high speed approximately 48,500 g.p.m. at low speed. The difference in heads between the No. 7 and No. 8 pumps and between the two No. 8 pumps was necessary because of dissimilar discharge circulating-water piping layouts imposed by station conditions.

POWER PHOTO

ABOVE AND BEYOND THE VALVES OF
NO. 6 TURBINE RISES THE MASS OF NO. 7

BUILT-IN TEST FACILITIES

GIVE CHECK ON PERFORMANCE

During design and purchase of equipment, methods of test were carefully considered, resulting in provisions for testing the turbines on the regenerative cycle, determination of condenser cleanliness factor and special arrangements for determining flue-gas dust loading and analysis.

By W. F. DAVIDSON

Director of Research
Brooklyn Edison Company

THE PRACTICE of the Brooklyn Edison Company is to make careful acceptance tests on all major equipment and to conduct other tests and investigations to provide data as a basis for improving the performance of existing equipment or aiding in the selection of new equipment. Hudson Avenue station is unusually well provided with facilities for such testing, and throughout the design of the station consideration has been given to test requirements. Locations for test connections are selected and equipment manufacturers are requested to make suitable provision as part of the regular installation. The valves are so arranged that not a single blank flange is necessary to isolate any turbine or north-end boiler from the rest of the station for test purposes. At all important points double valves with leak-offs between are provided. This arrangement is particularly satisfactory from an operating point of view, as it makes it possible to return without delay to normal operating conditions if emergencies make this necessary.

Weigh tanks (mounted on precision scales) and volumetric tanks are available in sufficient capacity to permit testing the largest turbine-generator units or for weighing water during boiler tests. Feedwater temperature can be controlled through a wide range by passing through one of the high-pressure extraction heaters which is arranged to permit isolated operation.

The electrical test facilities include those for making high-potential tests on cables and equipment. In addition an extensive layout of test circuits runs from a central instrument test room to all parts of the station. These make it possible to centralize all electrical metering during tests. They also afford a convenient means for setting up special communication circuits.

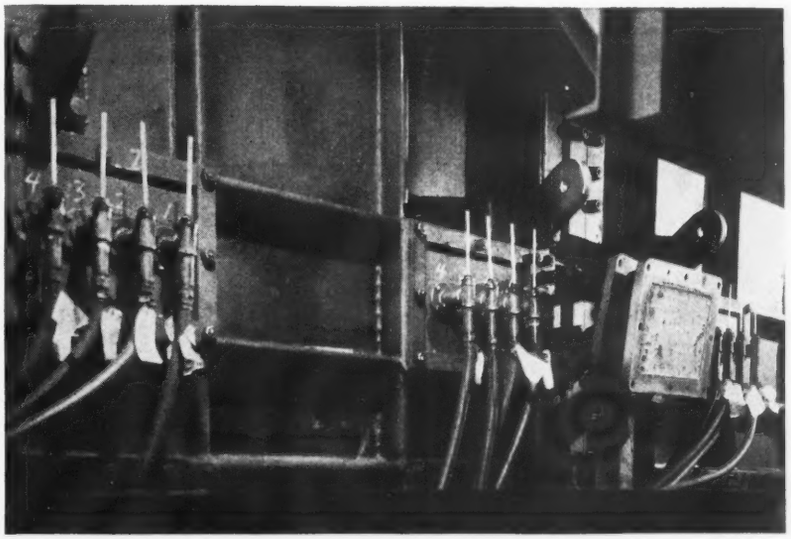


Fig. 1—Test set-up for determining condenser "cleanliness factor"

One of the special test methods developed by the Brooklyn Edison Company is the measurement of the degree of condenser-tube fouling. The A.S.M.E. Power Test Code on Condensers specifies that they must be thoroughly cleaned before acceptance tests are made. However, "thoroughly cleaned" is a somewhat indefinite condition, involving personal opinion to a large extent. General practice throughout the country has been to specify the manner of cleaning to be used, but even this is unsatisfactory where appreciable fouling occurs.

To overcome these difficulties it was decided to test the condenser in its normal operating condition and to correct the results to the guarantee conditions by the introduction of a "cleanliness factor." By "cleanliness factor" is meant the ratio of the heat-transfer coefficient of a tube doing normal service in the condenser to that of a new tube installed at the time of the test, with both tubes operating under identical conditions of circulating-water temperature and velocities and steam temperature and flow. The over-all tube cleanliness factor of the condenser is taken as the weighted average of the cleanliness factors of all the tubes.

Since it is obviously impossible to obtain a cleanliness factor from each tube in the condenser, calculations have been based on tests of a limited number of tubes in representative locations. Usually 25 or 30 tubes are selected and isolated by hose jumpers connected through special covers on the waterbox manholes. These tubes are grouped in banks, each consisting of three old tubes which have not been disturbed except to give them the same cleaning as is given the entire condenser before test and one or two new tubes installed near the center of the group just prior to the test.

The tubes are supplied with water from the same source as the main circulators and the velocity is adjusted by means of a valve and nozzle at the outlet of each tube so that it will be as nearly as possible at the normal value for tubes in that location. Inlet and outlet water temperatures are determined with glass thermometers.

All of the recent turbine-generator units in the station have been purchased with guarantees of performance based on extraction feed heating, and, consequently, acceptance tests have all been made on the regenerative cycle. Experience has shown that there are no serious difficulties in the way of making tests on this basis and that the results are considerably more satisfactory than if calculated on the basis of tests made with the unit operating straight condensing.

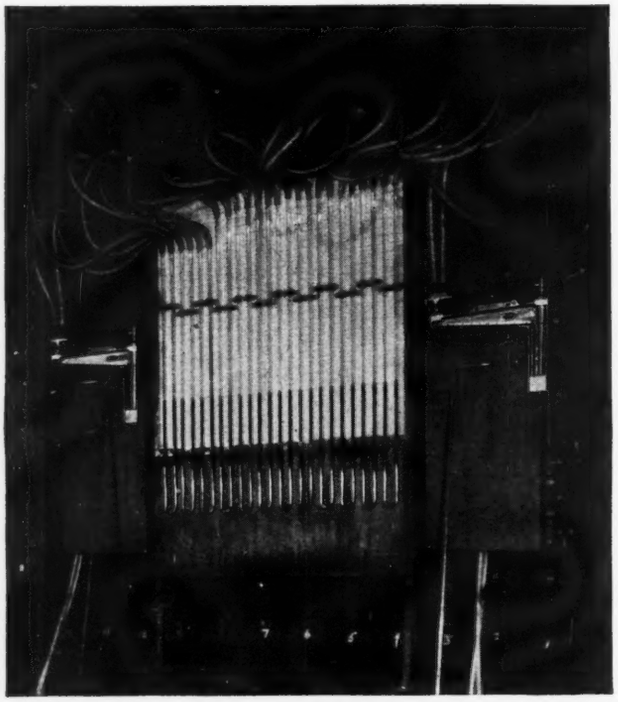


Fig. 2—Manometers are used to indicate the rate of gas flow through the samplers. Thermocouples and pitot tubes are used to determine velocity of the gas at the sampling points

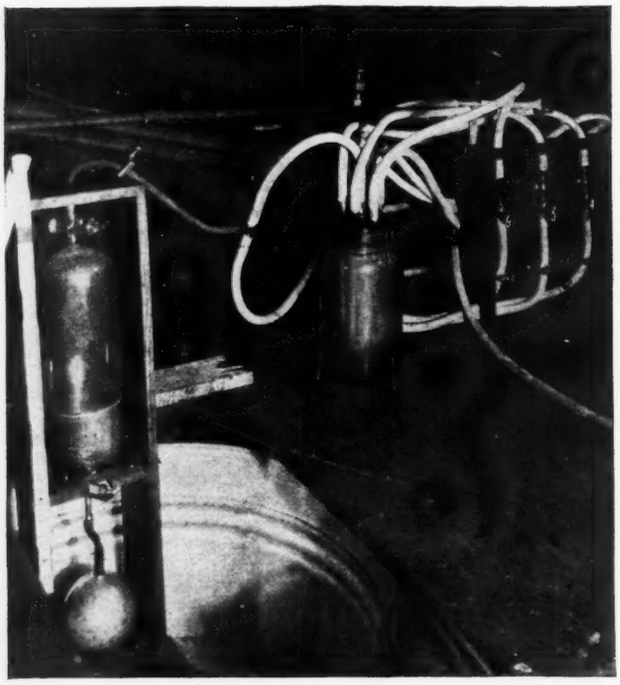


Fig. 3 — Flue-gas collecting apparatus used for obtaining continuous samples for laboratory analysis

Much work has been carried on during the past few years with a view to reducing the unaccounted-for losses on boiler tests. At high rates of combustion the cinder loss, hydrocarbon loss, and the carbon-monoxide loss (in excess of that indicated by Orsat analysis) may easily become of important proportions. Where wet types of cinder catchers are used it is impossible to weigh the cinders caught. Even with dry-type cinder catchers efficiencies are often so doubtful that the method is generally considered inadequate.

A method for measuring the cinder loss employed at Hudson Avenue with considerable success is based on the determination of cinder concentration by means of sampling units. Usually twelve cinder-sampling tubes are located at the centers of corresponding equal-area sections of the duct. Steam ejectors draw the cinders through the sampling tube at the same velocity as that of the gas in the duct at the sampling point. Duct velocities are determined by pitot tubes and thermocouple traverses. The velocity in the sampling tube is determined by a suitable orifice flow meter (Fig. 2).

From the sampling tube the cinder-laden flue gas passes into a glass jar, where it is filtered through a fine Monel metal screen if the temperature is high or a cloth bag if the temperature is low. The cinders remain in the jar while the gases pass on to the control valve and measuring orifice previously referred to. From the weights of gas sampled and the cinder collected the average cinder concentration (pounds of cinder per pound of gas) is easily computed and applied to the known quantity of flue gas.

Experience has indicated that accurate measurements of the carbon-monoxide and hydrocarbon content of flue gas are impossible to make in the field. The first problem in determining the loss due to these unburned gases is that of collecting average uncontaminated samples and transporting them to the laboratory. Fig. 3 shows the sampling apparatus used.

From six sampling lines uniformly spaced in the boiler outlet, the gas passes through glass orifices provided with manometers so as to indicate the rate of flow. From these orifice meters the gas is discharged into the bottom of a large mixing bottle from the top of which a composite sample is continuously drawn off by a water aspirator.

The sample for laboratory analysis is taken off by a connection to the side of the tube carrying the composite sample. Connection is made to a large glass flask filled with mercury and connected to a leveling bottle. By suitably adjusting the height of the leveling bottle and the stop cock in the connection, it is possible to draw in the sample at a uniform rate so that 500 c.c. will be collected in one hour, or 2,000 c.c. in four hours. Before disconnecting the flask sufficient mercury is forced into it to result in a slightly positive pressure so that in case of leakage there will be no contamination of the sample. This method entirely avoids contact of the gas with water and eliminates the uncertainties resulting from possible absorption. In the laboratory the carbon-monoxide content of the gas is determined with an iodine pentoxide train and the hydrocarbon content with a modified Burrell-Oberfeld gas-analysis apparatus.

Principal Mechanical Equipment in Hudson Avenue Extension

(In connection with Units No. 7 and 8, aggregating 320,000 Kw.)

Boilers and Furnaces

Manufacturer .....Combustion Engineer Corp.
Number and type: 8, three-drum (plus separate dry drum), bent-tube, with water-cooled furnace walls.
Heating Surface, sq.ft.: water-heating, 24,450; superheater, 5,740 (102 elements); water wall, 3,846.
Volumes and areas: furnace volume, 14,000 cu. ft.; projected grate area, 694 sq.ft.
Tube arrangement: first bank, 39 wide x 7 deep; superheater, 102 elements installed (space for 114); second bank, 48 wide x 8 deep; third bank, 48 wide x 7 deep.
Tubes, number and size: 993 tubes, 3-in. diameter of No. 8 B.W.G.
Drum dimensions: dry drum, 26 ft. ½ in. long outside x 48 in. I.D. x 2 in. thick; front drum, 34 ft. 4⅞ in. long outside x 54 in. I.D. x 2⅜-in. thick; rear drum, 34 ft. 4¾ in. long outside x 54 in. I.D. x 2½ in. thick; lower drum, 28 ft. 1⅞ in. long outside x 54 in. I.D. x 2½ in. thick.
Furnace walls: heating surface 3,846 sq.ft.; side wall of finned tubes; front wall of plain and finned tubes; rear wall of finned tubes; fireside walls of cast-iron blocks to av. height of about 5 ft. above stoker.
Casing: boiler, steel; furnace, transite.
Operating conditions: maximum steam output, 530,000 lb. per hr.; steam at superheater outlet, 440 lb. gage and 750 deg. F.; feed water to economizer, 275 deg. F.

Economizers

Manufacturer.....Combustion Engineering Corp.
Number and type: 8, C.E. return-bend, fin-tube, counterflow economizers with seamless steel tubes.
Dimensions: 928 fin tubes, 21 ft. long x 2 in. O.D. Total heating surface 22,400 sq.ft.
Blowdown valves .....Yarnall Waring Co.

Feed Water Regulators

Manufacturer.....The Swartwout Company
Number and type: 16 level-regulating valves and 16 constant-excess-pressure regulating valves.
Design features: size 6-in., 600 lb. standard; maximum capacity, 350,000 lb. per hour.

Stokers

Manufacturer.....American Engineering Company
Number and type: 8, Taylor underfeed, mechanically operated rams and secondary pushers, with double-roll clinker grinders.
Dimensions: 15 retorts; 69 tuyères; stoker 26 ft. 7¾ in. long x 26 ft. ½ in. wide; projected grate area, 694 sq.ft.
Stoker drive: Hele-Shaw hydraulic drive; pump unit direct connected to 40-hp., 720-r.p.m., 440-volt, 3-phase, 60-cycle Allis-Chalmers motor; speed of Hele-Shaw hydraulic motor varies from zero to 680 r.p.m.
Clinker-grinder drive: Hele-Shaw pump unit, driven by 5-hp. Allis-Chalmers motor, supplies oil under pressure to operate reciprocating pistons driving crusher rolls through ratchets and pawls.
Stoker guarantees: 530,000 lb. steam per hour for two hours; 452,000 lb. continuously.

Ash-Handling Equipment

Manufacturer.....Allen-Sherman Hoff Company
Type and capacity: "Hydrojet," 60 tons per hour.
Description: intermittent high-pressure water-jet sluiceway under ash hoppers; oil-operated ash pit gates; ash dumped onto sloping feed plates, cleaned to floor trench by high-velocity jet, then carried by stream to dock ash pit.

Ducts and Flues

Contractor.....M. H. Treadwell Company
Description: welded, with external stiffeners; some dampers equipped with dashpot retarding cylinders (Smoot Engineering Co.).

Cinder Catchers

Manufacturer .....M. H. Treadwell Co.
Number and type: 8 units; consisting of parallel enamelled plates, water-filled hopper, etc. (see page 812 for details).

Coal Gates

Manufacturer .....Link Belt Company
Number: 20 gates; 2 electrically operated gate-opening mechanisms.
Drive: General Electric 2½-hp., 1,200-r.p.m., 440-volt, 3-phase, 60-cycle motor.

Coal Lorries

Manufacturer.....Bergen Point Iron Works
Number, type and capacity: 2 lorries; one 20-ton motor-operated weigh lorry with non-automatic Winslow scale; one 5-ton motor operated lorry without weighing mechanism; both with traverse speed of 150 ft. per minute.
Drive: General Electric motors, 20-hp. and 75-hp., respectively, 900-r.p.m., 440-volt, 3-phase, 60-cycle.

Coal Cars

Manufacturer.....Whiting Corporation
Number and description: 3; 5-ton capacity; speed (full load), 230 ft. per min., drive, 5-hp., 1,200-r.p.m., 220-volt, 60-cycle, dust-tight, single-phase reversible motors.

Combustion Control

Manufacturer.....Smoot Engineering Company
General: "supermaster," "master" and individual controls for eight boiler units. (See page 809 for further details.)

Forced-Draft Equipment

Manufacturer.....B. F. Sturtevant Co.
Number, type and capacity: 7 "Turbovane," double-inlet, double-width, with vane control; capacity, 200,000 c.f.m. at 70 deg. F. against 10-in. static head.
Drive: Westinghouse motors, single-speed, squirrel-cage, 500-hp., 2,300-volt, 3-phase, 60-cycle, 900-r.p.m.

Induced Draft Equipment

Manufacturer.....B. F. Sturtevant Co.
Number, type and capacity: 16, "Turbovane," double-width, double-inlet, vane-control; capacity, 155,000 c.f.m. at 405 deg. F. against 20-in. static head.
Drive: Westinghouse motors three-speed, squirrel-cage, 2,300-volt, 3-phase, 60-cycle, 1,200/900/600-r.p.m. 1,000/450/200-hp.

Turbine-Generators

Manufacturer.....General Electric Company
Number, capacity, speed: two, 200,000-kva. 160,000-kw. at 80 per cent P. F., 1,800-r.p.m.
Type: tandem-compound, single-double flow, condensing, with 3-phase, 60-cycle, 16,500-volt generator and direct-connected exciter.
Steam conditions: throttle, 400 lb. gage and 730 deg. F.

Generator Air Coolers

Manufacturer.....General Electric Company
Description: closed air circuit; 8 condensate sections; 4 raw-water sections; 53,400 sq.ft. of cooling surface; 4 Buffalo Force Co. fans, 57,500 c.f.m. each, driven by 200-hp. 1,200-r.p.m., 2,200-volt induction motors.

Condenser and Auxiliaries—No. 7 Unit

Manufacturer. Worthington Pump & Machinery Corp.
Type: horizontal single-pass.
Dimensions and description: 14,710 tubes, ⅞-in. O.D. and 30 ft. 3¼ in. long.
Tube surface: 101,000 sq.ft. (0.631 per kw. of rated generator capacity).
Steam-jet air ejector One triple-element, Worthington, 2-stage unit with precooler, intercooler, aftercooler, and 2 hogging jets for starting.
Manufacturer of circulating pumps,
Worthington Pump & Machinery Corp.
Number, type and capacity: two (one right-hand and one left-hand), horizontal double-bottom suction, single-stage, volute centrifugal. Capacity 73,250 g.p.m. against 24 ft. T.D.H. at 220 r.p.m. and 48,500 g.p.m. against 14-ft. T.D.H. at 160 r.p.m.
Drive 600/250-hp., General Electric, 3-phase, 60-cycle, 2,300-volt, constant-speed, squirrel-cage motors.
Condensate pump. Worthington Pump & Mchy. Corp.
Number, type and capacity: two 2-stage, 3-impeller centrifugal; 3,000 g.p.m. at 880 r.p.m. against 180-ft. T.D.H.; 2,000 g.p.m at 705 r.p.m. against 130-ft. T.D.H.
Drive: two 225/115-hp G.E. 2,300-volt 900/720 r.p.m., 3-phase, 60-cycle 2-speed, pole-changing, squirrel-cage motors.

Condenser and Auxiliaries—No. 8 Unit

Manufacturer of condenser.....Ingersoll-Rand Co.
Type: horizontal, single-pass, with external cooler and condensate reheater.
Dimensions and description: 14,550 tubes, ⅞ in. O.D. and 30 ft. 3¼ in. long.
Tube surface, sq.ft.: condenser, 100,000; external cooler, 1,000; total 101,000; per kilowatt rated generator capacity, 0.631.
Reheater tube surface: 1,600 sq.ft.
Manufacturer of steam-jet air ejector,
Ingersoll-Rand Company
Number, description: two units, each with 8 primary jets, 3 secondary jets, intercooler and aftercooler, 2 hogging jets.
Manufacturer of circulating pump,
A. S. Cameron Steam Pump Works
Number, type and capacity: two, centrifugal, 72,750-g.p.m. at 192 r.p.m. against total head of 25 ft.; 48,500 g.p.m. at 128 r.p.m against total head of 11.5 ft.

Principal Mechanical Equipment in Hudson Avenue Extension (Continued)

Drive: 600 hp., General Electric, 2,300-volt, 3-phase, 60-cycle, 200/133-r.p.m., pole-changing, squirrel-cage induction motors.
Manufacturer of condensate pumps,
A. S. Cameron Steam Pump Works
Number, type and capacity: two, 3-stage, 4-impeller, centrifugal; capacity, 3,000-g.p.m. at 880 r.p.m. against 190 T.D.H.; 1,900 g.p.m. at 705 r.p.m against 128 ft T.D.H.
Drive: two 225-hp., General Electric, 2,300-volt, 900/720-r.p.m. 3-phase, 60-cycle, 2-speed, pole-changing squirrel-cage motors.

Feed-Water Heaters

Manufacturer .....Alco Products, Inc.
Type: Four-pass, closed.
High-pressure heaters, number and dimensions: two; 4,600 sq.ft. of ¾ in. tubes.
Low-pressure heaters, number and dimensions: two; 4,900 sq.ft. of ¾ in. tubes.

Boiler-Feed Pumps

Manufacturer..A. S. Cameron Steam Pump Works
Number, type and capacity: six, 5-stage centrifugal; Capacity 1,750 g.p.m. against total head of 1,450 ft.
Drive: six 850-hp., 2,300-volt, 60-cycle, 1,800-r.p.m. wound-rotor induction motors, direct connected through flexible coupling.

Heater Condensate Pumps

Manufacturer .....Buffalo Steam Pump Co.
Number, type and capacity: Three, single-stage, double-suction centrifugal; capacity 575 g.p.m. at 75 ft. T.D.H.
Drive: 20-hp., 3-phase, 60-cycle, 440-volt, 1,750-r.p.m. General Electric motor.

House-Service Pumps

Manufacturer...Worthington Pump & Machy. Corp.
Number, type and capacity: two, horizontal, single-stage centrifugal; capacity, 4,000 g.p.m. against 185 ft. T.D.H.
Drive: 250-hp., 1,800-r.p.m., 3-phase, 60-cycle, 2,300-volt, 4-pole, squirrel-cage motors.

Fan Bearing Cooling Water Pumps

Manufacturer.....Ingersoll Rand Company
Number, type, capacity and drive: two centrifugal, 60 g.p.m. against 25 ft. T.D.H.; drive, 1.5-hp. squirrel-cage, 1,750-r.p.m. motors

Surge Tanks No 5 and 6 (With new section)

Manufacturer.....M. H. Treadwell Co.
Number and size: two, 7,800 gal. capacity.

Oil Pump for Combustion Control

Manufacturer..Worthington Pump & Machy. Corp.
Number, type and capacity: two, single-stage centrifugal; capacity 40 g.p.m. at 104-ft. T.D.H.
Drive: 5-hp., 440-volt, 3,510-r.p.m. squirrel-cage motor.

Piping

The order for the 600-lb. seamless steel tubing for main-steam and feed-water service was placed with the Almirall Supply Company, who subcontracted with the Midwest Piping & Supply Company to furnish the tubing and fabricate it into piping ready for erection. The latter company placed an order for the tubing with the Seamless Tubing & Steel Company of Pittsburgh, Pa., who secured it from the Düsseldorf Tube Works of Vereinigte Stahlwerke, Germany.

The 600-lb. castings for main steam and feed-water service were furnished by the Reading Steel Casting Company.

The R. H. Baker Company erected the above tubing and casting material, and also furnished and erected the remainder of the piping.

The main steam piping was fabricated with Globack laps and flanges. Joints were made up with Kell-Raph gaskets, Republic Steel Corporation studs, and Bethlehem Steel Company hot pressed nuts.

The boiler-feed piping was fabricated with Globack laps and flanges. The joints were made up with Consolco gaskets using the same bolting material as on the main steam line.

Valves

Number and Type.....Manufacturer
Four, 42-in. atmospheric relief..Atwood & Morrill Co.
Two, 18-in., four 24-in. bleeder check valves.
Two, 4-in. threeway globe valves for air leakage meters.
Two, 2½-in. vacuum-breaker valves for surge tanks.
Two, 6-in. and one, 4-in. float-operated makeup valves .....H. Belfield Co.
Forty-eight flanged plug valves (4-in. & 6-in.) for boiler & cinder catcher drains,
Chapman Valve Mfg. Co.
Six Bleeder gate valves.
Four, 6-in. water-relief valves for feed heaters,
Consolidated Ashcroft Hancock Co.
Two, 2-in. needle angle valves for central oil system.
One, ½-in., 600-lb. gate valve.....Crane
Two, 10-in., 125-lb. globe valves for vacuum breakers.
Thirty-two safety valves,
Crosby Steam Gage & Valve Co.
Eight, 16-in. automatic stop and check,
Edward Valve Mfg. Co.
Misc. forged steel globe.
Drum-head 6-in. stop checks for boiler feed.
Misc. 125-lb. gate valves and pop safety valves,
Lunkenheimer
General 600-lb. globe and lift-check valves,
Wm. Powell Co.
General low-pressure globe angle and check valves. Main steam, boiler feed and general 600-lb. gate valves, check valves and "Limitorque" motor operators..Reading-Pratt & Cady, Inc.
Two, 4-in. flow indicators...Schutte & Koerting Co.
Four, 22-in. throttle valves.
Sixteen, 2½-in. straight-way....Yarnall-Waring Co.
Sixteen, 2½-in. angle; thirty-two, 1⅛ in. angle.
Sixteen, 1½-in. straight-way blow-off valves.

Insulation

General contractors.....Asbestos Construction Co.
High-temperature insulation: "Superex" block,
Johns-Manville Co.
Magnesia block.....Johns-Manville Co.
"Stictite".....Refractory & Engineering Corp.
Piping insulation: "Superex" and magnesia molded blocks, finished in sizes 10 in. and above with asbestos cement. Flanges and fittings on piping covered with block insulation wired in place in sizes 5 in. and above, applied in same thickness as on corresponding piping, and in sizes 4 in. and below covered with "Stictite." Feed-heater bodies, tanks and drip receivers covered with "Stictite."
Insulation for ducts and flues: magnesia blocks finished with asbestos cement.
Boiler insulation subcontractors.....R. H. Keasby
Boiler insulation manufacturer.—Philip Carey Co.
Materials used: asbestos sheathing for furnace water walls and boiler front walls; Magnesia blocks for drums, risers and downtakes.

Mechanical Meters and Instruments

Two, Vacuum columns (condenser),
Taylor Instrument Co.
One hundred seven, Thermometer test wells,
C. J. Tagliabue Mfg. Co.
Sixteen, 5-pt. draft gages (boiler panels),
Paul B. Huyette Co.
One, 7-pt. draft gages (control-room panel).
Eighteen, Temp. and press. recorders..Foxboro Co.
Two, Liquid-level recorders (surge tanks).
Two, Indicating press. gages (feed pumps),
Consol. Ashcroft Hancock Co.
One, Indicating press. gages (ash-sluice pump),
Ashton Valve Co.
Ninety-three, Indicating press. gages,
Crosby Steam Gage & Valve Co.
Eight, Recording resistance thermometers (gen. air coolers).....Leeds & Northrup Co.
Two, Elec. operated flow meters (boiler feed),
Bailey Meter Co.
Two, Elec. operated flow meters (condenser makeup).
Eight, Sets of boiler meters (boiler panels).
Eight, Elec. temp. recorders (boilers),
Brown Instrument Co.
Two, Diff. press. recorders (gen. air coolers),
Foxboro Co.
Four, Flow meters (Main and heater condensate) .....Builders Iron Foundry
Thirty-three, Industrial thermometers,
Taylor Instrument Co.
Two, Dial thermometers (turb. gland).
Eight, Single-tube hydraulic draft gages (windbox press).....Ellison Draft Gage Co.
Sixteen, Double-tube hydraulic draft gages (grates).
Eight, Double-tube hydraulic draft gages (windbox and furnace).
Eight, Inclined hyd. gages (Bailey air flow).
Two, Comb. inclined—vertical draft gages (test).
One, Salinity recorder (8-point recorder for Units 1-8 inclusive).....Leeds & Northrup Co.

Station Data (Units 7 and 8 Only)

Boiler House Area, sq.ft.	18,000
Steam generated per sq.ft., lb. per hour	235
Volume, cu.ft.	3,000,000
Steam generated per cu.ft., lb. per hr.	1.4
Entire Unit Areas, sq.ft.	
Boiler house	18,000
Turbine room	9,500
Switch house	9,000
Dock	7,000
Total	43,500
Power concentration, kw. per sq.ft.	7.4
Volume, cu.ft.	
Boiler house	3,000,000
Turbine room	1,100 900
Switch house	900,000
Total	5,000,000
Power concentration, kw. per 1,000 cu.ft. bldg. vol.	64

Present Business Problems Feature Program of N.E.L.A. Convention

WITH BUSINESS as its keynote, the program of the 55th convention of the National Electric Light Association, to be held in the Atlantic City Auditorium during the week of June 6 to 10, will be devoted to a consideration of topics of immediate importance to the power industry. Addresses and papers will deal specifically with such present problems as load-building developments and plans, effect and future of the machine age, economic aspects of research and engineering, sales and merchandising programs.

The exhibition, to be held in conjunction with the convention, will be devoted to the latest equipment and services of manufacturers, designed to reduce production costs, improve service and increase loads.

The program is as follows:

FIRST GENERAL SESSION

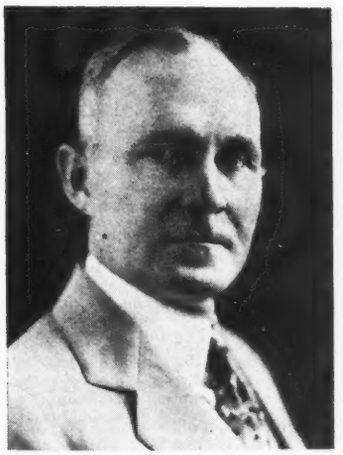
Tuesday Morning, June 7

Address of welcome, Mayor Bacharach.
Presidential address, J. F. Owens.
Address, "The N.E.L.A.—Its Work and the Electrical Industry," B. C. Cobb, chairman finance committee.
Report of committee on constitution and bylaws, R. F. Pack.
Treasurer's report, Edward Reynolds, Jr.
Report of Public Relations National Section, D. C. Green.
Address, Charles F. Kettering, president General Motors Research Corporation.
Address, B. F. Weadock, executive director.

ENGINEERING SESSION

Tuesday Afternoon, June 7

Chairman's report, A. H. Kehoe.
Address, with demonstration of new technical developments, Samuel M. Kintner, vice-president Westinghouse company.



J. F. OWENS
President, N.E.L.A.

Address, "Engineering as Process of Business," J. C. Parker, president Brooklyn Edison.

ACCOUNTING SESSION

Tuesday Afternoon, June 7

Chairman's address, J. H. Lobban.
Address, W. Paxton Little, chairman advisory council.
Discussions on financial subjects by selected speakers.

SECOND GENERAL SESSION

Wednesday Morning, June 8

Address, Vice-President P. M. Downing.
Report of Commercial National Section, T. O. Kennedy.
Report of exhibition committee, E. W. Goldschmidt.

COMMERCIAL SESSION

Wednesday Afternoon, June 8

Chairman's address, T. O. Kennedy.
Address, President J. F. Owens.
Report of Electric Refrigeration Bureau, J. E. Davidson.
Report of home-lighting committee, W. A. Jones.
Report of National Electric Cookery Council, P. S. Arkwright.

THIRD GENERAL SESSION

Thursday Morning, June 9

(Edison Memorial Session)

Address, Thomas N. McCarter.
Address, "What the Machine Is Doing to Mankind," James S. Thomas, Alabama Power Company.
Report of Engineering National Section, A. H. Kehoe.

PUBLIC RELATIONS SESSION

Thursday Afternoon, June 9

Chairman's address, D. C. Green.
Address, "Taxation," George T. Buckingham, vice-president Illinois Power & Light Corporation.
Addresses by prize-winning speakers in national employees' speaking contest and presentation of awards by President Owens.

PUBLIC POLICY SESSION

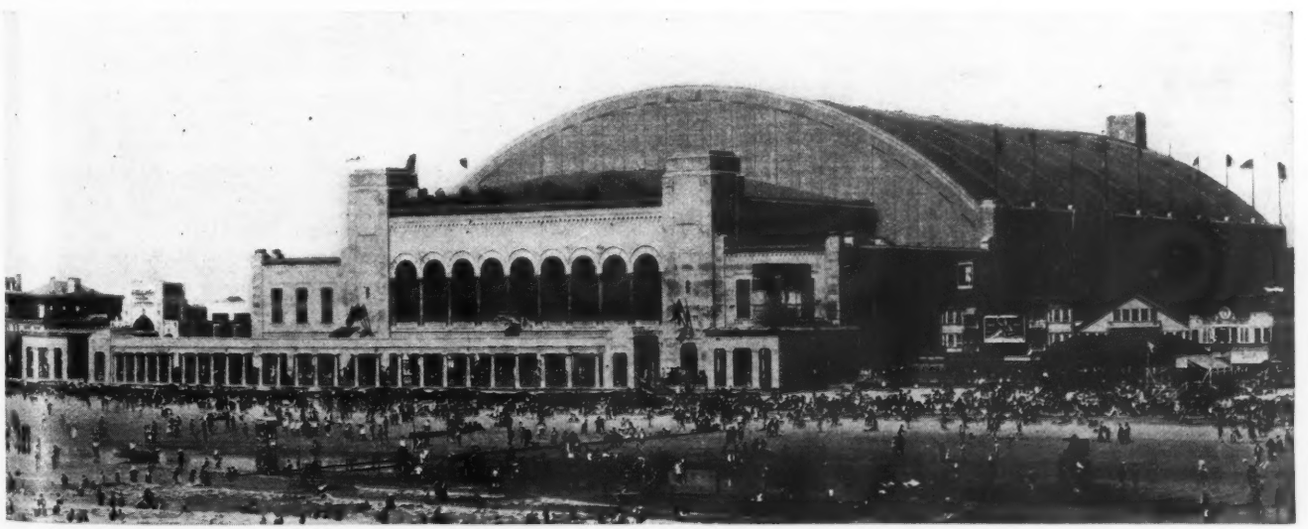
Thursday Evening, June 9

Address, Floyd L. Carlisle.
Report of public policy committee, P. S. Arkwright.

FOURTH GENERAL SESSION

Friday Morning, June 10

Report of memorial committee, W. H. Onken, Jr.
Report of prize awards committee and presentation of awards, Frank W. Smith.
Report of Accounting National Section, J. H. Lobban.
Address, "Public Interest in Electrical Merchandising," Kenneth Dameron, secretary joint merchandising committee.
Address, "New Tools for the New Age," C. M. Ripley, General Electric Company.
Election of officers.



Atlantic City Auditorium where the convention sessions and exhibition will be held

How's Business?

The week's records are not especially promising for those expecting speedy improvement in the business picture under pressure of credit expansion efforts. Most indicators showed some relapse in the level of industrial and trade activity from the first half of May as well as somewhat less favorable features in the financial situation. The unseasonal strengthening in steel output since the outset of the month has slackened slightly as automotive summer schedules are revised, but June is expected to bring a peak in car production, and some stimulus for structural steel demand is coming forward from increasing public construction. Car loadings, electric power output (1,435,731,000 kw.-hr. for the week ended May 21, according to the N.E.L.A.) and check payments reflect further contraction in manufacturing activity and retail trade.—*The Business Week*, June 1.

BUSINESS NOTES

FARVAL CORPORATION, 3277 East 80th St., Cleveland, Ohio, has recently acquired the manufacturing and sales rights of the Farval centralized system of lubrication. This equipment was formerly manufactured by Lubrication Devices, Inc., Battle Creek, Mich. A. J. Jennings, formerly vice-president of Lubrication Devices, is now general sales manager of the Farval Corporation. Distribution of the Farval equipment for the central industrial section of the country is being handled by the Dingle-Clark Company, with offices in Cleveland, Cincinnati, Pittsburgh and Philadelphia.

WESTINGHOUSE ELECTRIC SUPPLY COMPANY, East Pittsburgh, Pa., has elected J. S. Tritle vice-president in charge of operations. Mr. Tritle is also vice-president and general manager of the Westinghouse Electric and Manufacturing Company.

FARREL-BIRMINGHAM COMPANY, Ansonia, Conn., has appointed as sales representatives George L. Hurst, 785 Market St., San Francisco, Calif., and J. R. Brown, 2710 First Central Trust Bldg., Akron, Ohio.

MERCON REGULATOR COMPANY, Chicago, Ill., has appointed the following district representatives: E. F. Espenschied, 1008 Hill Bldg., Washington, D. C.; M. N. Dannenbaum, 709 Bankers Mortgage Bldg., Houston, Tex.; Cowles and Company, 721 Mercantile Bank Bldg., Dallas, Tex.; Boiler Equipment Service Company, 686 Greenwood Ave., Atlanta, Ga.; and Cothran-Bayles Company, Commercial Bank Bldg., Charlotte, N. C.

New Bulletins

PUMPS—Bulletin 1650, Type "S" Centrifugal Pumps, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

STEAM ENGINES—"How 6 Representative Concerns Cut Power Costs," Troy Engine & Machine Company, Troy, Pa.

STEAM CONDUITS—Booklet on underground steam construction, Underground Steam Construction Company, 75 Pitts St., Boston, Mass.

BOILERS—Bulletin B-32-3, various types of boilers for stationary and marine plants, Foster Wheeler Corporation, 165 Broadway, New York, N. Y.

CIRCUIT BREAKERS, METER — Circulars 1937 and 1939 on the new line of "De-ion" circuit breakers; Circular 1938 on the new Type OC watt-hour meter, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

STOKERS—Three bulletins covering chain-grate stoker, underfeed stoker and automatic overfeed stoker, respectively, Niagara Combustion Corporation, 150 Portage Rd., Niagara Falls, N. Y.

FLOW METERS—Bulletin 690, high-torque flow meters, Cochrane Corporation, 17th St. Bel. Allegheny Ave., Philadelphia, Pa.

BOILER BAFFLE WALLS—Folder on "The Beco-Turner Baffle Wall," Boiler Engineering Company, 744 Broad St., Newark, N. J.

New Plant Construction

Compiled by the McGraw-Hill Business News Department, Which Is Prepared to Furnish a More Complete Daily Service to Those Who Wish It

Calif., Santa Rosa—Grace Bros., 9th and Wilson Sts., plans to rebuild cold storage plant destroyed by fire. Loss $200,000.

Calif., Wilmington—Los Angeles Department of Water & Power, 207 South Broadway, Los Angeles, appropriated $61,000 for construction of power plant here. H. C. Gardett, 207 South Broadway, Los Angeles, is engineer.

Ill., Chicago—Wieboldt Realty Trust, 1637 Ogden Ave., awarded contract for construction of a 13 story apartment building at 133 South Ashland Ave. to R. C. Wieboldt Co., 1412 West Washington Blvd. Estimated cos $1,500,000. Maturity in 1933 pending financing.

Ill., Rock Island—Board of Local Improvements, plans construction of pump house and pipe to connect to present trunk sewer including 700 to 88 g.p.m. pump. Estimated cost $25,000. Wallace Treichler, City Hall, is engineer.

Ind., Laporte—City having plans prepared for construction of light plant. Estimated cost $100,000. Private plans.

Ind., New Castle—DePauw University, having revised plans prepared for construction of a steam heating plant. Estimated cost to exceed $40,000.

Ia., Dubuque—Fischer & Co., 300 Iowa St., plans to expend between $150,000 and $200,000 for changing artificial ice manufacturing plant from d.c. to a.c. and substitution of electrical energy from Interstate Power Co. for their own steam plant. Contracts awarded for switchboard and motors to Ideal Electric & Mfg. Co., Mansfield, O., and ice machines to William Figge, Dubuque.

La., New Orleans—U. S. Engineer Office, First New Orleans District, Poland and Dauphine Sts., will receive bids until June 21 for power house superstructure, power house plant, electrical equipment, oil and pump house, miscellaneous equipment, etc., for New Vermilion Canal Lock in Intracoastal Waterway, Vermilion River.

Mass., Tewksburg — Department of Public Welfare, plans changes and equipment in power house at State Infirmary. Private plans. $31,200.

Mass., Worcester—Reed & Prince Manufacturing Co., Duncan Ave., will not construct Diesel power plant, etc., on Cambridge St. $100,000. F. J. Sill, East Main St., Westboro, Engr. Project postponed indefinitely.

Mich., Dearborn—Ford Motor Co., Schafer Road, awarded contract for construction of a new power sub-station at River Rouge Works to Martin-Krausman Co., 955 East Jefferson St., Detroit. Estimated cost $75,000.

Minn., Duluth—City, c/o John Wilson, City Engr., completed plans for construction of pumping stations and chlorination plant in connection with sewage disposal system. Estimated cost $200,000.

Neb., St. Edwards—City, H. W. Rich, Clk., will soon award contract for construction of municipal light and power plant and distribution system, including switchboard, engines, etc. Estimated total cost $56,805. C. V. Barnhill, 416 Federal Trust Bldg., Lincoln, is engineer.

N. Y., Brooklyn—H. Silver, 499 Pennsylvania Ave., having plans prepared for construction of a 1 story, 40 x 97 ft. market building including refrigeration plant at Livonia and Sheffield Aves. S. Millman & Son, 1780 Pitkin Ave., are architects.

N. Y., Long Island City—National Sugar Refining Co., 55th Ave. and Second St., receiving bids on general and separate contracts for addition and alterations to power house at 56th Ave. and West Second St. L. T. Bromfield, c/o owner is engineer. Generator purchased.

N. Y., New York—Board of Transportation, J. H. Delaney, Chn., 250 Hudson St., awarded contract for furnishing and installing auxiliary power equipment for Queens line of Independent system of City-owned Rapid Transit Railroads, Borough of Queens, to L. I. Waldman & Co., 241 East 36th St., New York. $368,000.

O., Franklin—Chaney Pulp & Paper Co., plans to rebuild paper manufacturing plant and boiler house destroyed by explosion.

Pa., Huntingdon—Department of Property & Supplies, John L. Hana, Secy., Harrisburg, will receive bids about June 1- for construction of a boiler house including piping, electric wiring, etc. here. I. H. Francis, 1520 Locust St., Philadelphia, is engineer.

Pa., Kennett Square—A. D. Pierce, awarded contract for construction of a slaughter house including refrigeration and equipment to William N. Horrall, 220 South Union St., Kennett Square.

S. D., Hot Springs—Interstate Oil & Refining Co., completed plans for construction of a Diesel engine-electric power house at mining properties, Mule Creek. Estimated cost $40,000 including equipment.

Va., Quantico—Bureau of Yards & Docks, Navy Department, Washington, D. C., will receive bids until June 8 for extension of steam mains to quarters and replacement of coal burning equipment boilers and water heaters with steam converters and coil type water heaters at Marine Barracks, here.

Wash., Seattle—Board of Public Works, received lowest bid for completion of Diablo hydro-electric project including Diablo power house superstructure to be erected on existing foundations; power house tail race complete; assembly and erection of power house machinery previously purchased and now at site consisting of two 67,500 kva. generating units, step-up transformers and auxiliary equipment; furnishing and installation of switchboard, control wiring, switches and switch structures and other equipment to make a completely operative power station, etc., from Bayley-Hopkins Inc., Eitel Bldg. Total $1,744,705.

B. C., Port Alberni—National Utilities Corp. Ltd., Port Alberni, subsidiary of British Columbia Power & Gas Co. of Vancouver, will receive bids in June for construction of a 30 x 65 ft. power house. Estimated cost $70,000. Private plans. Contracts for Diesel engine and generator, awarded.

Ont., Toronto—Upper Canada College, Avenue Road and Lonsdale Rd., plans expansion to present property including boys' building, service building, artificial ice rink, etc. Estimated cost $400,000. Mathers & Haldenby, 96 Bloor St. W., are architects.

Equipment Wanted

Boiler and Condenser—Springfield, Ill.—City will receive bids latter part of June for boiler and condenser for city light and power plant.

Control and Metering Equipment—Columbus, O.—Department of Public Welfare, Ninth and Oak Sts., J. McSweeney, Dir., will receive until June 20 for combustion control and metering equipment for power plant at Ohio Penitentiary.

Electrical Equipment—Philadelphia, Pa.—Department of City Transit, A. Davis, Dir., City Hall Annex, will receive bids about June 3 for furnishing and installing and relocating electrical equipment in sub-station in connection with subway.

Engines—Washington, D. C.—General Purchasing Officer, Panama Canal, will receive bids until June 15 for two Diesel engines, direct reversing to develop 400 hp. each at 250 r.p.m.

Generators—Washington, D. C.—Division of Purchases & Sales, Department of Commerce, will receive bids until June 10 for 30 to 50 direct connected gasoline driven generators 3 kva. capacity. Pro. 24410.

Generators—Brooklyn, N. Y. and Mare Island, Calif.—Bureau of Supplies & Accounts, Navy Department, will receive bids until June 7 for 80 gasoline engine driven electric generaators.

Power Plant Equipment—Washington, D. C.—Bureau of Supplies & Accounts, Navy Department, will receive bids until June 7 (extended date) for power plant equipment.

Pump—Topeka, Kan.—City will receive bids about June 1 for a 4,000 g.p.m. motor driven pump at North Topeka pumping station, also moving two old pumps from North Topeka to Madison St. station.

Pumps, etc.—Monmouth, Ill.—City plans to purchase three sludge pumps, two air compressors, flow recording mechanism, sludge collecting machines, mechanical agitators, etc. in connection with sewage disposal plant. Estimated cost $100,000.